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THESIS

**THE IMPLEMENTATION OF IS ON THE KNOWLEDGE
MANAGEMENT AND MENTAL MODELS AT THE
DECISION-MAKING PROCESS**

by

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March 2011

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AND MENTAL MODELS AT THE DECISION-MAKING PROCESS**

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ABSTRACT

The emphasis of this research is to leverage Knowledge Flow Theory to enhance extant Decision Theory and decision support systems to improve the decision-making process in military organizations in general and to outline a research agenda for subsequent application to the Hellenic Navy. Thus, the challenge of this research effort is to expose the major factors that define the problem of the decision maker for correct decisions through their synthesis.

The areas of the dynamic knowledge as well as the mental models have special gravity among the military personnel since they determine the decision making process. Therefore, the intention of the author will be to conduct an introduction of the existed literature and provide greater fidelity and insight into the mechanism within which the emerging technology can either support or in some cases improve our decisions. Hence, the basis of this thesis is to enlighten the technological approach for timely integrated decisions.

The method that will be followed focuses on theoretical integration and is expected to result in a general decision-making process for the military that reflects explicit incorporation of Knowledge Flow Theory.

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LIST OF ACRONYMS AND ABBREVIATIONS

AOO	Area Of Operation
AP	Access Point
ASW	Anti-Submarine Warfare
BPS	Bits per Second
C2	Command and Control
CENETIX	Center for Network Innovation and Experimentation Situation Awareness
C.G	Coast Guard
CISSP	Certified Information Systems Security Professional
CMIP	Common Management Information Protocol
COI	Conditions of Interest
CPU	Central Processing Unit
CWA	Cognitive Work Analysis
dB	Decibel
dB _i	Isotropic Decibels
DoD	Department of Defence
FCC	Federal Communications Commission
ID	Identification
IPSEC	Internet Protocol Security
IS	Information Systems
IT	Information Technology
JFC	Joint Forces Command

KBS	Knowledge-Based Systems
LAN	Local Area Network
MANET	Mobile Ad Hoc Networks
MBPS	Megabits per Second
MCN	Model-Based Communication Network
MHz	Megahertz
MIO	Maritime Interdiction Operations
MOE	Measures of Effectiveness
MoD	Ministry of Defense
MOP	Measures of Performance
NCOW	Network-centric Operations and Warfare
NCW	Network Centric Warfare
NDP	Naval Doctrine Publication
N.M	Nautical Miles
NMIOTC-GR	NATO Maritime Interdiction Operational Training Center - Greece
NMS	Network Management System
NOC	Network Operation Center
NPS	Naval Postgraduate School
OODA	Observe-Orient-Decide-Act
QOE	Quality of Experience
QOS	Quality of Service
RADHAZ	Radiation Hazard
RF	Radio Frequency

RMP	Recognized Maritime Picture
RPD	Recognition-Primed Decision
SATCOM	Satellite Communications
SME	Subject Matter Experts
SNMP	Simple Network Management Protocol
SNR	Signal to Noise Ratio
TNT	Tactical Network Topology
UWB	Ultra Wide Band
VIRT	Valued Information at the Right Time
VPN	Virtual Private Network
WAN	Wide Area Network
WMD	Weapons of Mass Destruction

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I. INTRODUCTION

One of the most enduring lessons derived from the history of warfare is the degree to which fog and friction permeate the battlespace. The fog of battle is about the uncertainty associated with what is going on, while the friction of war is about the difficulty in translating the commander's intent into actions. Much of the fog of war, or what is referred to today as a lack of battlespace awareness, has resulted in the inability to tap into collective knowledge, or the ability to assemble existing information, reconcile differences, and construct a common picture. There needs to be equal emphasis placed upon developing a current awareness of both friendly and enemy dispositions and capabilities, and in many cases, there needs to be increased emphasis on neutrals (Alberts, Garstka, & Stein, 2000).

The modern era, which is known as the Information Age, has created an environment where collaborative decision-making can be employed to increase combat power. This is partly because of the emergence of coalition operations, partly because of the distribution of awareness and knowledge in the battlespace, and partly because of the compression of decision timelines. This alone would be challenging enough, but the Information Age has also transformed the problem of warfare from a series of static events to a more continuous one by greatly increasing the operating tempo of events. The result is the need for greater integration between the heretofore separate planning and execution processes, which requires more timely interactions between the two, and portends an ultimate merging of these two processes into a seamless form of command and control.

Therefore, the Information Age has changed the way one reaches decisions, allocates decision responsibilities within the organization, develops options and evaluates them, and the manner in which one chooses among them. This has obvious implications in how one designs systems and trains people, which becomes the necessity for more in-depth analysis for their causes.

During the last decades, scientists have started enlightening the domain of human knowledge. Additionally, their research has driven them to produce mental models that attempt to explain the mechanism that analyzes and synthesizes the components of that knowledge in order to exploit the results for improving the decision making process.

The technological evolution of the Information Age affects decisions, discovering or generating new areas to invest in, and requiring more knowledge that develops a self-reinforcing cycle of research. To this end, it is also true that the continuous race for more knowledge that decreases the uncertainty, subsequently forces people to rely even more on the technology that provides better, faster and cheaper solutions for the proper management of the received information.

One of the most frequently leveled criticisms, by those who think that the “creature” will never be able to substitute for or even worse overpass its “creator,” is that the reliance on information technologies (IT) (sensors, data processing, communications subsystems.) carries an inherent weakness that opponents can exploit—the vulnerability of such technologies to offensive information warfare, or “hacking.”

Do information technologies carry an electronic Achilles' heel that opponents can exploit? Are people losing the control of their inventions? If so, heavy reliance on the system-of-systems, which is the current goal of the military (and not only) technology for integrated solutions, might make the user vulnerable to catastrophic failure in efforts to use it successfully in conflict.

There is great danger in relying on military systems that have exploitable flaws. Indeed, the characteristic that gives any system its potency for enhanced effectiveness due to their complexity also makes some systems susceptible to catastrophic failure if one of their central parts can be jeopardized.

On the other hand, the difference between the visionary leader and the “system-of systems” is his unique ability to recognize, identify, and adapt his vision upon which he will develop his decisions that mitigate the above-mentioned risks.

The uniqueness of the human instinct, which is based on explicit and tacit knowledge, is rather difficult to be copied and reproduced by any other system (at least with the current technology). There are some aspects of the system-of-systems that ought to alleviate, if not refute, these concerns in order for the future to accelerate the decision-making process.

First, one needs to recognize that there is no need to wait until someone else finds a potential vulnerability; instead, one needs to think and work continually to find and eliminate it first.

Next, one needs to eliminate the search for secured systems and start incorporating risk management. A race will probably always exist between those who seek to ensure the security of information-based systems and those who seek to overcome their security measures. That does not mean that one has to curse the technology for being vulnerable, but rather one has to educate himself/herself for the best and most efficient handling and managing of the systems' abilities for his/her benefit.

Finally, one has to appreciate the fact that the systems are tireless and can be replaced instantly or provide a robust redundancy that works against the possibility of breaking the whole system; characteristics that people cannot provide or at least it requires an extended amount of time, effort and resources for doing so.

Hence, none of these weaknesses is cause for complacency; one needs to continually keep in mind potential vulnerabilities and work hard to find and end them. Neither can be assessed that a closer collaboration between man-machine in the decision-making process carries more risk if people trust the technology than sticking with the current and more human-oriented status quo.

Thus, one needs to create new **(dynamic) knowledge** that follows the changes of the operational environment and will allow for recognizing the benefits of exploiting the emerging technology that focuses on the cognitive domain rather than the material one. Furthermore, recognizing that today's decisions are based on a plethora of information available to everyone at no cost requires **superiority** that will offer the competitive advantage among the opponents and the ability to appreciate the **systemic pathologies** of

the **decision-making process** that covers many facets. Having said that, one can value the efforts and the willingness for transformation of the Armed Forces to meet what the **network centric concept** dictates, in order to elevate the collaboration and the knowledge sharing that ameliorate and accelerate the decision making process. Therefore, after all these terms governing one's daily routine, one needs to analyze each and every one of them in order to appreciate their gravity and significance in the military reality.

A. THE DYNAMIC KNOWLEDGE

Knowledge represents a critical resource in the modern enterprise that conceptualizes the competitive advantage offered by the intellectual capital of an organization (Grant, 1996; Nissen, 2002).

Capitalizing on this resource for enterprise performance depends upon its rapid and efficient transfer from one organization, location or time of application to another. From a technological perspective, such dynamic dependence points immediately to the design of information systems (IS)—along with the corresponding organization and process characteristics (Leavitt, 1965; Davenport, 1993)—to enhance knowledge flow. However, knowledge is distinct from information and data (e.g., it enables direct, appropriate action; see Davenport, De Long, and Beers, 1998; Teece, 1998), and few extant IS even address knowledge as the focus or object of flow (Nissen, 1999).

In addition, the charisma of leadership that distinguishes the successful leader from the followers within an organization either in the military or in a business environment is a combination of skills and knowledge gained through the education and training that constitute the whole of his/her personality. This personality is extremely difficult to be copied or transferred to others without losing critical parts of it.

Furthermore, the role that the mental models play for the decisions that one builds is rarely understood although these cognitive constructs not only provide a basis for interpreting what is currently happening, they also strongly influence how he/she acts in response.

According to Senge, “[The] mental models of what can or cannot be done in different management settings are no less deeply entrenched” (Senge, 1990, p. 8).

Moreover, due to the technological revolution that occurred as a result of the exploitation of unlimited knowledge, the role of the IS has been upgraded, providing both supportive and performative means to the decision-making process that address issues at the time, completeness and accuracy realms (Nissen, 2006).

These three factors have a distinguished gravity in the military environment since they define the results of an operation that most of the time affects the sovereignty and existence of a nation as a whole.

B. THE DECISION-MAKING PROCESS

The constantly changing nature of routinely made decisions in an organization is based on their involvement with the results of other interrelated decisions that were made in the past, or they have to be made in parallel with the current ones as a common practice of a higher strategic plan.

It has been argued that in dynamic environments, outcome feedback acquires the property of being corrective feedback (or negative feedback in a cybernetic sense) in that it permits adjustments. Decision makers can, therefore, rely on outcome feedback through a judgment-action-feedback loop to make effective decisions. (Sengupta & Abdel-Hamid, 1993)

Cognitive feedback is conceptualized as information provided to a decision maker about (a) the relations in the decision environment, (b) relations perceived by the person about that environment, and (c) relations between the environment and the person's perception (Balzer, Doherty, & O' Connor, 1989).

Additionally, the research shows that there are three types of information that correlate the environment and the decision maker:

1. *Task information*, or information about the cue-criterion relationships in the environment;
2. *Cognitive information*, or information about the cognitive system of a decision maker; and

3. *Functional validity information*, i.e., information about the relation of the cognitive system to the task system (Balzer et al. 1989).

Therefore, every decision is a combination of interconnected factors and “players” that constitute the whole.

C. THE SYSTEM AS A WHOLE

Everything and everyone are connected components of a larger web. As the great Argentinean author Jorge Luis Borges (1998) quotes, “There's no need to build a labyrinth when the entire universe is one” (p. 260). There is an interrelation of social, economical, religious and professional or even personal interests that connects everyone within a worldwide network. Perhaps that was also the primary reason for the rapid success of the Internet and the World Wide Web (www) just after their first public introduction and literally boosted their implementation rate and performance, becoming part of one's daily life.

Today we increasingly recognize that nothing happens in isolation. Most events and phenomena are connected, caused by, and interacting with, a huge number of other pieces of a complex universal puzzle. (Barabási, 2003, p.7)

Indeed, the necessity for fast and reliable communication, exchange of ideas, information gathering, education and/or quick and accurate calculations and simulation models has been provided, almost in total, by the Internet, thus drastically reducing the traditional ways that are characterized as isolated or “old fashioned.”

Thus, decisions require the collaboration of many different partners, reducing the characterization of leaders as “great men” that used to be given in the past and rather introducing the term “leader” as designer.

Leaders who appreciate organizations as living systems approach design work differently. They realize that they can create organizational artifacts like new metrics, or formal roles and processes, or intranet web sites, or innovative meetings- but it is what happens when people use the artifacts or processes or participate in the meetings that matters. (Senge, 1990)

These “leaving systems,” according to Senge, demand the conquest of knowledge that comes through the information superiority in order to achieve better and faster decisions.

D. INFORMATION SUPERIORITY

Deterrence, power projection, and other strategic concepts are greatly affected by the ability to influence the perceptions and decision making of others. Thus, frequent, instant, and reliable access to information available inside and outside the operational area (ensuring the uninterrupted collection, processing and dissemination of that information) is required. These information infrastructures could inhibit a commander’s ability to control the flow of information or dynamically manage available information while denying an adversary’s ability to do the same.

In addition, the same factors are also crucial in the business world, since they provide the means for achieving the required competitive advantage within the market arenas that will boost a company to become leader in its field. At the same time, they provide the analogous “competitive advantage” among services or between adversaries.

In both cases (i.e., the military and the business word), the environment is highly dynamic and most of the time uncertain and unpredictable relative to the results of a decision that a commander/manager is called on to make for addressing a certain situation. This became the genesis of the network-centric concept, in an effort to decrease the uncertainty through the instant dissemination of information that allows for the creation of integrated decisions.

E. NETWORK-CENTRIC WARFARE

Rapidly advancing information-based technologies combined with the increasingly competitive global environment have thrust information into the center stage in society, government, and warfare in the 21st century. Information and information-based technologies are pervasive, and impact every facet of warfighting, from planning,

deployment, sustainment, post-conflict, and redeployment processes to the plethora of forces and weapons systems employed by JFCs (Joint Force Commanders) and their component commanders (JP 3-13).

The predominance of the technological evolution on the information superiority arena against the knowledge and skills that are required from the end user in order to operate effectively is perfectly illustrated in Figure 1.

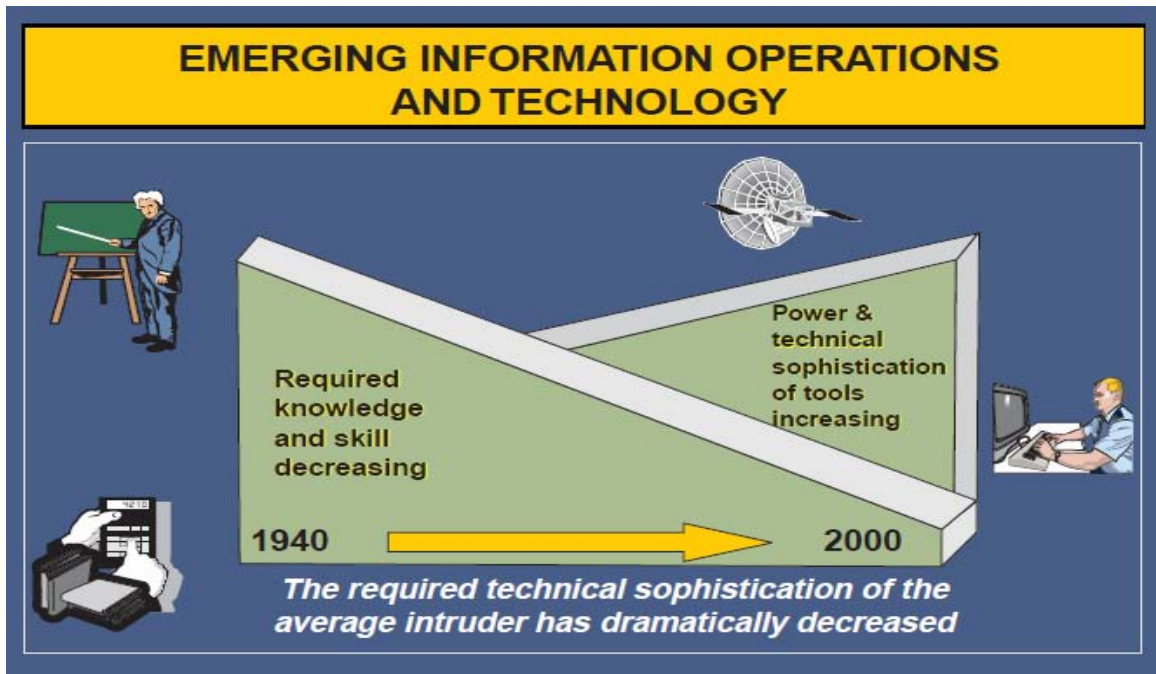


Figure 1. Emerging Information Operations and Technology (From JP 3-13, p. I-16)

What might be misleading is that the end user will not be the generator or the originator of the information-based technology, but only the one who exploits its capabilities. Thus, the necessity for more knowledge as technology evolves is even bigger in order to achieve the effective processing of the information for the sake of the information superiority.

F. THE MOTIVATION

Following all the above-mentioned concepts like dynamic knowledge, the reliance on the information technology and the relevant risks, the decision-making process and the information superiority that governs it, and the network-centric concept, were some of the challenges that the author was confronted with. This became the motivation for his thesis research -in order to expose the major factors that define the problem of the decision maker for correct decisions through their synthesis as a whole following the concept that Fritjof Capra introduces in his book “The Web of Life,” stating that “...the whole is more than the sum of its parts” (Capra, 1996, p. 31).

In a similar approach, Dr. Abdel-Hamid argues in his book “Thinking in Circles About Obesity” that:

The great shock of twentieth-century science has been that systems cannot be understood by analysis... The performance of any system (whether it is an oil refinery, an economy, or the human body) obviously depends on the performance of its parts, but a system's performance is never equal to the sum of the actions of its parts taken separately. Rather, it is a function of their interactions (Ackoff, 1994). These interactions (and their properties) are destroyed when the system is dissected, either physically or theoretically, into isolated elements. Breaking a system into its component pieces and studying the pieces separately is, thus, usually an inadequate way to understand the whole. (Abdel-Hamid, 2009, p. 27)

That is the reason for the decision making process to be addressed as a “system”, meaning the “...integrated whole whose essential properties arise from the relationships between its parts...in fact the meaning of the word “system”derives from the Greek *synistamai* (“to place together”)” (Capra, 1996, p. 27).

This same concept also explains the reason why viable solutions are the ones that are sustainable on the realm of time without transferring or producing new problems for the future.

The above-mentioned simplified approach of a human being to his/her problems is based on the misleading notion of his/her linear nature that follows the instinctive attempt to analyze everything that occurs to its components. What is rather difficult to

understand from the beginning is that most of the time the same components that are connected either differently or at different analogy can produce numerous different results. For example two parts of hydrogen and one part of oxygen under the influence of temperature can produce gas, water, melted ice, ice, and perhaps many other results with different characteristics and behaviors.

Therefore, there are no simple or single answers to people's problems since today people have moved from the simplicity of living to the complexity of operating under a dynamic environment, which is the challenge of this thesis research. The question that the author will try to answer is as follows: "How can, an understanding of dynamic knowledge, be leveraged to improve the military decision-making process?" In order to achieve that, the thesis will follow a structure that consists of five chapters.

G. THESIS LAYOUT

The first chapter provides an overview of the thesis' problem domain and an introduction of dynamic knowledge, drawing upon the existing literature. Sequentially, the second chapter builds a rich multidimensional representation of dynamic knowledge under the prism of decision theory, demonstrating potential implementation of the emerging technology that is borrowed from the existed literature. Continuing with the third chapter the author analyzes the decision-making pathologies and synthesizes the proposed interventions that address those problems. In the following chapter the author discusses the results that occur from the synthesis of the gathered information, providing an experimental approach that is intended to offer greater fidelity and insight into the decision-making process, borrowed from the MIO (Maritime Interdiction Operations) experience of the NMIOTC-GR (NATO Maritime Interdiction Operational Training Center-Crete, Greece). Finally, this research effort ends with conclusions that provide an agenda for continued research along the lines of this work.

Therefore, the author will follow the path of knowledge that starts from a signal that is being received, and that signal constitutes data that is processed to become information. Then, this information will be further analyzed and with the exploitation of the already existing explicit and/or knowledge tacit will generate new knowledge.

Finally, this new concept will be the basis for innovations, problem solutions and actions in general that will affect performance. Thus, the decisions that have to be made at each stage of knowledge will determine the quality and quantity of the final product.

H. THE EXPECTED CONTRIBUTION FROM THE RESEARCH

The existing literature dictates that knowledge management and mental models are two areas of extreme research interest, since the implementation of IS technology on them has a significant gravity on the modern military (and not only) environment.

There is no shortage of exaggerated claims, unfounded criticisms, and just plain misinformation about this subject. Sorting out fact from fancy will be among the author's tasks as he struggles with how to apply network-centric concepts (a relatively new idea) to military operations.

Since the successful adoption of the network-centric warfare (NCW) requires a cultural change, it cannot be achieved without widespread discussion, debate, experimentation, and ultimately, broad acceptance. If this effort stimulates and contributes to this process, it will have achieved its intended effect.

Modern armies move through this (NCW) direction that underlines the synergy and self-synchronization that is required between knowledge, mental models and Information technology. Therefore, it is a rather new research field that gathers a lot of interest not only because of its sensitive nature of understanding but also because of its wide implementation especially from the decision making perspective.

The method that will be followed focuses on theoretical integration and is expected to result in a general decision-making process for the military that reflects explicit incorporation of knowledge flow theory.

Further, this thesis research seeks to enrich the poorly understood dynamic phenomenon of the knowledge flow process, which facilitates mental models that materialize the implementation of IS technology for the sake of the improvement of the decision-making process.

Thus, the intended result is the maximization of efficient knowledge flow through the exploitation of emerging technologies that requires resident knowledge in order to succeed, while the successful transfer of usable knowledge is the genesis of this research, within the framework of the decision making process.

It is not within the intention of this enterprise to underestimate the gravity that the human mentality has to that process, but rather to appreciate how the technology can support human beings for the sake of response time, completeness and accuracy that is required for every one of the decisions that an officer in command is called to take.

The author will try to present an approach to the variables that determine the complexity of the decision-making problem in addition to the principles of the leadership that govern the mental process of such decisions.

Moreover, this thesis research will attempt to provide the required scientifically supported information about the pathologies of knowledge, how can be managed, proposing interventions that address them, emphasizing the complexity and difficulty of a decision-making process.

II. INTELLECTUAL CAPITAL AS A FORCE MULTIPLIER

A. KNOWLEDGE IS POWER

Force has no place, where there is need of skill

(Herodotus, “The Histories of Herodotus”)

From the fossil and archaeological record, there is good evidence that most of human history was marked by an incredibly negligible growth of knowledge. Even in historical times, whole centuries passed with few advances in knowledge. That changed a few hundred years ago starting with the Renaissance, and knowledge has been increasing since then at an accelerating rate. Recently, machines implemented the techniques of trained microbiologists, computers processed the data to identify valid hypotheses, and other computer programs automatically documented the results (Hayes-Roth, 2006).

Therefore, in this chapter the author discusses knowledge management, providing some basic theory upon the path of knowledge (data-information-knowledge) and how the dynamic complexity of the military environment and the uncertainty add more complication to the decision makers. In addition, the author tries to underline the question whether technology participates as a major enabler or a minor contributor to the decision-making process, presenting some means and methods that are used for the improvement of the knowledge flow.

B. WORK SMARTER RATHER THAN HARDER

In a complex and rapidly evolving environment the optimum results of one's efforts come when one works smarter rather than harder. In other words, the way that people produce, develop or operate is not any more a function of their hard work to accomplish more tasks, because the plethora of data and information exceeds their ability to understand and absorb the amount of knowledge that is required. Thus, people need to focus their efforts on improving the process of handling and managing existing knowledge and generating knowledge for their benefit.

To this end, people need to understand the differences between the data that is dispersed everywhere—in their daily activities, working environment, nature, etc. —the information that requires certain skills and previously gained knowledge in order to be appropriately processed, and the generation of new knowledge that comes as a result of education, training and experience.

The difficulty is that there are not unique definitions of the terms although their meanings are similar. As Table 1 shows, there is a variety of expressions that address the same terms but from different perspectives according to the interest of the scholar.

Author	Data	Information	Knowledge
Choo, Deltor, & Turnbull (2000)	Facts and messages	Data vested with meaning	Justified, true beliefs
Davenport & Prusak (1998)	A set of discrete facts	A message meant to change the receiver's perception	Experiences, values, insights and contextual information
Nissen (2006)	Data are operationalized best as interpreted signals that can reduce uncertainty or equivocality	Information is operationalized best as providing meaning and context for action.	Knowledge is operationalized best as enabling direct action
Nonaka & Takeuchi (1995)	-	A flow of meaningful messages	Commitments and beliefs created from these messages
Quigley & Debons (1999)	Text that does not answer questions to a particular problem	Text that answers the questions who, when, what or where	Text that answers the questions who, when, why and how
Spek & Spijkervet (1997)	Not yet interpreted symbols	Data with meaning	The ability to assign meaning
Wiig (1993)	-	Facts organized to describe a situation or condition	Truths and beliefs, perspectives and concepts, judgments and expectations, methodologies and know how

Table 1. Definitions of Data-information-knowledge (After Stenmark, 2002)

Moreover, there are different schools of thoughts that support either the clear distinction between data, information and knowledge (Nissen, 2006) or the argument that due to the difficulty of the clear separation of the terms there is a “continuum” of the three (Davenport & Prusak, 1997).

However, Nissen, Davenport, and Prusak agree that there is close interrelation between data, information, and knowledge. Drawing from Nissen (2006), one notionally structures the knowledge hierarchy as triangle-shaped using two dimensions—abundance and actionability. Data lie at the bottom level with information in the middle and knowledge at the top. The broad base of the triangle represents the abundance that exponentially decreases with the move from data to knowledge. On the other hand, the height of the triangle reflects the actionability (i.e., one’s ability to take direct action) which increases with the move from data to knowledge.

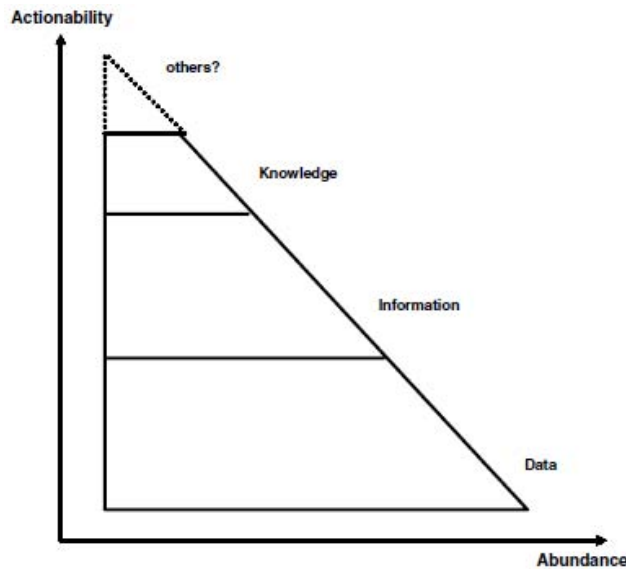


Figure 2. Knowledge hierarchy or the path of knowledge (From Nissen et al., 2000)

C. THE PATH OF KNOWLEDGE (DATA-INFORMATION-KNOWLEDGE)

1. Data

Data is the plural of datum, which in Latin according to the Merriam-Webster Dictionary (2003) means, “factual information ... used as a basis for reasoning or

interference” (p. 316). Other dictionaries or information technology sources present similar descriptions of the word as was discussed earlier on. Thus, data is something really basic that does not provide any obvious benefit to the user unless it is processed; it is like a word out of context.

For example, the numbers 20, 5, 10, 2, and 2 are meaningless unless they participate within a context. Then, they can have many different interpretations when they enhance the meaning or provide comparison measures to the factors that constitute the parameters of a hypothesis (scenario). These different interpretations are ruled by the environment within which the hypothesis is built. Different kinds of knowledge (e.g., language, experience) are required for different kinds of actions (e.g., interpretation, informing) related to the knowledge hierarchy (data-information-knowledge) (Nissen, 2006). Therefore, if that environment was the planning of a naval operation then, these numbers could gain some context (meaning) that translates the simple data into information. This “translation” requires the personal involvement of the user (his/her understanding and experience) in order to become processed material that can be further developed to generate knowledge. According to Dr. Nissen, “...the message recipient can interpret the signals (i.e., for data) and ascribe meaning (for information) to the message *but cannot take action* (for knowledge) without additional knowledge” (Nissen, 2006, p. 18). However, before getting to that point one needs to understand that the pieces of the collected data may represent information depending on the understanding of the one perceiving the data.

Therefore, in order for the data to be exploitable information, it requires some processing that will select the necessary elements for building one’s objectives, hypothesis, or scenarios; otherwise, data are useless.

So, initially there is a need for systems that gather these data in order for the user to find the interrelation among them that makes sense, or in other words, that gives meaning to them. The IT systems that are capable of selecting and gathering data have certain characteristics according to their scope and specifications. Hence, a metric system that provides a common basis for evaluating these systems is required, and some of these metrics are presented in Table 2.

Metric Category	Typical Data-Level Metrics	Description
Detection: ability to detect objects, events	Detection probability False alarm rate Miss probability	Probability of detection on single look False alarms per coverage Probability of fail to detect on single look
State estimation: ability to associate and estimate kinematic state	State accuracy Track accuracy Track persistence Correlation error probability	Accuracy of x, y, z and derivatives Accuracy of derivatives predictions Sustained estimation, dynamic target Probability of miscorrelation
Identification: ability to classify objects, events	Probability ID ID accuracy	Probability of correct ID Aggregate accuracy of ID decisions
Timeliness: time response of sensor/processing	Observation rate Sensing delay Processing delay Decision rate	Rate of revisits to observe object Delay from observation to report Delay from sensor report to decision Rate of update of output decision updates

Table 2. Representative Measures of Performance (MOPs) for a Military Command and Control System (From Waltz, 1998)

According to the description of each one of the metrics, one can understand the significance that the probability and uncertainty have on every aspect of technology and how critical it is for their outcome to minimize these factors for the level of quality and quantity of the process that produces information.

2. Information

Information is more than just data from which it is derived. Through processing, data is placed in a context, related to other data or previous information, and developed into something that is consumable by its users. Thus, the data transferred through

intelligence, social networks, or other communication links is still raw material since it has not been processed or developed, in order to be evaluated and then handled as information.

Therefore, continuing with the author's case of the planning of an offensive naval operation, the meaningless numbers, 20, 5, 10, 2, and 2 receive meaning if it is known, for instance, that the enemy has: a) 20 major combat ships and b) 5 of them are under maintenance or repairs with c) an average of 10 days to be required for them to be operational under conditions (according to the length of their repairs), d) in addition to 2 warships that are detached and deployed abroad, participating in an international commitment which requires e) at least 2 days of full-speed cruising in order to be able to return to their home ports. Then, one has a good estimation that for the first two days of operations (if the attack is started today) the enemy will have less than two-thirds of their ships available to fight (under certain restrictions). Moreover, if the weather forecast predicts clear skies on Monday and Tuesday and foggy weather for the rest of the week for a certain area, this is just data based on statistics and predictions that do not add any value to one's objectives. However, if the Area of Operation (AOO) is that specific area and the decision is to start the attack on Tuesday, limiting the time for the adversary's Air Force to respond, then, the significance of that information changes.

Hence, the collection of simple facts (i.e., data), does not provide any element or indication of the adversaries' readiness and operational capacity. However, if someone gathers all the data and has the ability (explicit and tacit knowledge) to analyze the situation and synthesize the "picture" behind the numbers, then one will be able to estimate the actual capabilities and perhaps predict the resistance that should be expected if one was planning to attack at a specific time. To this end, the author realizes the existing interrelation between data, information and knowledge, since, for the case being presented, one generates new knowledge of the adversary's capabilities, which is produced by the proper matching of the data with their context. After the data's intellectual processing (information) one "creates" a picture in his or her head about the current operational status of the enemy (knowledge), which is a result of one's education-training-experience. However, the author will analyze later on this chapter the principles

of knowledge in order to encapsulate the interrelation and how data, information, and knowledge complement one another. Thus, for the moment, the author will maintain the logical approach of understanding the relationship between data and information as it has already been introduced.

From a more technical approach that also falls under the same logic concept, the network traffic of the communication links—due to their structure—just packages the data into packets. These packets will be delivered to their destination where they will then either be stored as (useless for the moment) data or be further developed (they will receive some meaning). In other words, data that is not used, meaning processed, does not provide any information to the user.

The abstract nature of these concepts makes it difficult to see a clear way to measure the value of information, even though there are established ways to quantify and characterize the associated data. Often a small amount of information will have greater value than large amounts; thus, there is no direct relationship between the quantity of data and the value of the associated information. Although these two concepts are closely related, their relationship does not necessarily reflect their quantitative analogy.

For this reason, it would be a mistake to use purely communication metrics (such as throughput and bandwidth) to analyze information operations and evaluate their performance.

a. What Is the Value of the Information?

Moreover, in the military environment where command and control are required for the orchestration of all operations, the efforts to reduce the uncertainty at a reasonable point (elimination of uncertainty would be a utopia) dictates the gathering of useful information, generating knowledge derived from the triad of education, training, and experience.

Therefore, the need to design cost-effective information protection architectures adds new urgency to this classic problem. The biggest mistake system evaluators can do is equate information and data and evaluate the information warfare

performance of systems from a purely data communications perspective. Within the context of overall information operations, a bandwidth-efficient distributed system transmitting a smaller number of bits is very likely to be a better system than one that dumps large amounts of raw data on its users. The reason being is that the information is an understanding of the relationships between data or between data and other information, and the addition of unnecessary data does not add any value to the already existing knowledge, which is the requirement for all one's efforts. Especially when one is dealing with the dynamic complexity that characterizes the majority of the military operations, the notion of valued information plays a significant role for the successful outcome of a mission.

b. "Dynamic Complexity"

According to Naval Doctrine Publication 6 (NDP-6) that discusses command and control principles, gathering information increases the commander's understanding of the situation but it will never remove all the uncertainty (NDP-6, p. 12). Thus, sometimes the pursuit of more information can lead the commander to be confused or misled. As Clausewitz (1984) said, "...a great part of the information obtained in war is contradictory, a still greater part is false, and by far the greatest part is uncertain" (p. 75).

As knowledge about a situation increases, the ability to make an appropriate decision also increases. Knowledge is a function of information. Davenport and Prusak (1997) argue that

Knowledge is information with the most value and is consequently the hardest form to manage. It is valuable precisely because somebody has given the information context, meaning, a particular interpretation; somebody has reflected on the knowledge, added their own wisdom to it, and considered its larger implications...the term also implies synthesis of multiple sources of information over time. (p. 9)

Hence, as the quantity of information increases the effectiveness of the decision also should increase. At some point in the process, however, when basic knowledge has been gained and the quest for information focuses more on filling in

details, a point of diminishing returns is reached. At this point, the potential value of the decision does not increase in proportion to the information gained or the time and effort expended to obtain it. As the amount of information increases to this certain point, knowledge is increasing and the time needed to make an effective decision is decreasing. Beyond this point, additional information may have the opposite effect. It may only serve to cloud the situation, impede understanding, and cause the commander to take more time to reach the same decision he or she could have reached with less information, simply because he or she consumes precious time on analyzing useless or unnecessary information for the current mission.

Today's emerging technology enables commanders and their staffs to access in near-real-time extended amounts of information relating to every aspect of the current operational environment. This provides an integrated recognized operational picture (either in the maritime, land, or air domains) that covers the conditions, circumstances, and influences that affect the employment of capabilities and bear on the decisions of the commander. Hence, information will be available for matters related to friendly, neutral, and enemy forces and the civilian populace. In addition, the commander will be able to plan, organize, and execute his or her plans while maintaining an equally large volume of information concerning weather, terrain, cultural influences, and other aspects of the operational environment. This mass of information, when subjected to an analytical process, can be distilled into intelligence to support a predictive estimate of adversary capabilities and intentions. Consequently, this intelligence will become gained knowledge (for the commander) about the mentality and the strategy that the adversaries have and execute.

If not managed properly, sensors and information systems can overwhelm the commander with more information than he or she can process and understand in time to make decisions. It is the current level of the commander's knowledge that will allow him or her to clarify the value of the data and the gravity of the information that is required to generate new knowledge, improving the decision-making process according to the mission's objectives. Thus, the failure of technology to produce dramatic

improvements in the decision-making process, when the amount of information increases, is caused by the “dynamic complexity” that Peter Senge introduces in his “Fifth discipline.”

When the same action has dramatically different effects in the short run and the long, there is dynamic complexity. When an action has one set of consequences locally and a very different set of consequences in another part of the system, there is dynamic complexity. When obvious interventions produce non obvious consequences, there is dynamic complexity. (Senge, 1990, p. 71)

c. The Uncertainty of Military Operations

In the already dynamic and complex military environment, uncertainty adds more complication to the decision maker pervading in all military operations. This ambiguity covers the unknown factors that affect a commander’s estimation about the adversary and his intentions, about the environment, or even about his or her own forces. Nevertheless, the nature of combat will always make absolute certainty impossible to attain. It is important to understand that certainty is a function of knowledge and not of information. The two are clearly related, but the distinction is that important information is the raw material from which knowledge is generated. Knowledge results from people adding meaning to information through the process of cognition when they match patterns that already exist with the processed new information generating something new.

Such an integration of people, doctrine, technology, and information allows a commander to gain situational awareness, reach decisions about courses of action, and implement those decisions by means of plans and orders. Hence, the command and control system encompasses not only the equipment and technology that support its mission, but also the leadership, training, organization, and doctrine that guide it.

Although there is no single way that information can be evaluated—simply because each of the recipients has a different understanding and different background to receive the appropriate message that the information hides—there is no doubt that information has context and a value basis. Therefore, this value is derived from

the efforts and the required resources (people, infrastructure, budget, etc.) for gathering that information, or the significance that it offers to the current operations, which accelerates the results for the sake of the objectives.

d. How Does Information Add Value?

The value of the information is a function of the user, the user's intentions, what others intend to do with it, and the expected and/or actual outcomes. In addition, as the author has already mentioned, value depends also on other factors such as resources. Therefore, knowledge cannot be derived without the understanding of how valuable information matches with the available resources in order to achieve objectives.

Consider the following example of a computer software evaluation as it has been adopted from Dr. Myron L. Cramer.

The source code for this software would carry great value to a competitor who could use it to gain insights into program design and techniques. It would have almost no value to someone who lacked the ability or resources to compile the program, and who only had use for the executable code. To a third person also lacking the software development capability but without ethical restraints of the second person, the source code might have value based on its marketability to competitors of the developer. (Cramer, 2005)

Thus, it is now clearly understood that information without other components cannot be fully exploitable unless it has been further processed and correlated with the appropriate factors. The emerging technology that the modern IT systems provide offers solutions that accelerate the performance and support processes in order to achieve higher effectiveness and efficiency.

Therefore, a certain number of metrics that characterize the capacity and capabilities of these systems helps retrieve the figure of merit that technology can add to processes for better, faster and more accurate information that sequentially can generate new knowledge, which supports the final objectives.

A representative table with the measures of effectiveness (MOEs) of a military command and control system that handles information is shown in Table 3.

Metric Category	Typical Information-Level Metrics	Description
Capacity: ability to handle the information flow volume and rate	Throughput Surge process rate Correlation rate Data leakage rate Storage (look-back capacity)	Rate of translation of data to intelligence Maximum short period rate Rate of correlation of data elements Rate of loss of uncorrelated data items Capacity to store past data reports
Awareness quality: degree of vigilance and use of all available data	Correlation accuracy Detection Identification Geopositioning accuracy Prediction accuracy Plan accuracy	Accuracy of associations between datasets <i>P</i> detection/ <i>P</i> false alarm operating characteristic <i>P</i> correct ID type ID accuracy Spatial accuracy for targeting Temporal/spatial behavior predict accuracy Feasibility of alternatives planning
Timeliness: speed with which information is processed and products are delivered to users	Time to accumulate Time to generate alternatives Time to project Time to plan and select Time to decision	Accumulation delay to awareness decision Time to create alternative explanations, Extrapolation time for projections Time to synthesize response plans Composite decision-making time

Table 3. Representative Measures of Effectiveness (MOEs) for a Military Command and Control System (From Waltz, 1998)

Like in data collection systems, the “uncertainty principles” also affect outcomes since there are many reasons why it is difficult to achieve precision when dealing with information. Therefore, in the information realm one has to deal with some level of acceptable approximations. The reason being is that there will always be some amount of uncertainty that will be proportional to the information’s time window and the associated information bandwidth within this timeframe. Although one may be able to calculate different factors that influence the information, it is difficult to tabulate statistical data on something in cyberspace; it is too intangible.

e. The Sensitivity of Information

Since information is sensitive and crucial for the successful outcome of operations it needs to be properly handled and protected.

(1) Access and Security Principles. According to the Certified Information Systems Security Professional (CISSP) publication, “*Access* is the flow of information between a subject and an object. A *subject* is an active entity that requests access to an object or the data within an object” (Harris, 2008, p.155). Thus, the control of the access provides the ability to monitor, protect and manage the confidentiality, integrity and availability of information.

It is time to define these characteristics that determine the value of information. “*Confidentiality* is the assurance that information is not disclosed to unauthorized individuals, programs, or processes” (Harris, 2008, p. 157). Hence, some of the mechanisms that assure the confidentiality of information are the encryption, logical and physical access controls as well as control traffic flows. To this end, sensitive information (like enemy capabilities, potential courses of action or movements of forces, etc.) that needs to be exchanged between component commanders requires the utility of encrypted environment (Internet Protocol security (IPSec)) encryption protocol) that virtual private networks (VPNs) and the like offer.

Integrity characterizes the information that is accurate, complete and protected from unauthorized modifications. Therefore, any illegitimate alteration of the context or the sender/receiver details violates the reliability and thus, the value of the information. A control mechanism that assures (with some limited notion of risk) the integrity of the transmitted information is the electronic signature. According to U.S. law, an electronic signature is “an electronic sound, symbol, or process, attached to or logically associated with a contract or other record and executed or adopted by a person with the intent to sign the record” (U.S. Public Law 106–229, 2000). More depth on this subject is out of the scope of the research project.

Finally, the *availability* of information means that information has to be available to users in a timely manner. Fault tolerance and recovery mechanisms can assure the uninterrupted availability of resources that allow for the continuation of

operations. Commanders use these concepts within their planning process to develop strategic or executable plans according to their objectives, realizing the significance of the protected information.

(2) Information Assets. The mission or the strategic vision communicates the purpose of the military structure to the staff. The individual processes utilize technologies and facilities, which are operated by knowledgeable staff and are supported by the organization's databases. Information assets are integrated into all of these in different ways; the value and risks to these information resources are different.

Type	Description	Leverage	Risks
MISSION	Communicates organizational mission	Directs plans, processes, staff, data bases	Availability, integrity
PLANS	Results from planning process to organize and control resources to accomplish mission	Directs, resources, and controls processes, staff, and data	Availability, confidentiality, integrity
PROCESSES	Technologies and processes to produce products	Affects interconnected processes	Availability, integrity
DATA BASES	Operational and technical data bases used by planning and other processes	Affects processes	Availability, integrity, confidentiality
STAFF KNOWLEDGE	Knowledge and know-how of staff, reflecting education, training, and experience. Knowledge of business procedures, technical knowledge, customer experience, and market understanding	Affects ability to plan and execute processes	Availability

Table 4. Information Assets (From Cramer, 2005)

3. Knowledge

The concepts of “center of gravity” and economic warfare have been employed throughout military history. Controlling information (in a time effective manner) and manipulating perceptions at the crucial point in a campaign have always been desirable, but may have been technologically difficult to achieve. Perhaps now there is that capability and it must be known how to plan campaigns using these concepts supported

by technology in both offensive and defensive roles. There is a need to properly manage knowledge in order to make better, faster and more integrated decisions.

Thus, there is a need to recognize the patterns that exist between processed information. These patterns embody both a consistency and completeness of relations which, to an extent, create their own context. In addition, they serve as “archetypes,” according to Peter Senge, with the characteristics of repeatability and predictability (Senge, 1990). Hence, the pattern relation between data and information can represent knowledge only when one is able to recognize and identify these patterns and their implications, enabling direct actions. Therefore, the relationship amidst data-information that meets a certain pattern creates its own context, which represents knowledge only when it is understood by the interpreter who acts accordingly.

To this end, the commander must meet objectives to accomplish a mission. Therefore, he or she needs to interpret the “right pattern” in order to gain the required knowledge. There will be obstacles in the path that must be overcome (enemies, etc.) and he or she can either go through them or around them. At the risk of oversimplifying the situation, physical weapons offer many options for going through an obstacle and information “weapons” offer options for going around. One must realize, however, that neither information weapons nor physical weapons work alone!

Only when they work together (each filling in the voids where the other cannot be used for physical, political, financial, or other reasons), can they truly strengthen the commander's ability to efficiently and effectively reach mission objectives.

Basically the commander wants to take the best of Clausewitz¹ and the best of Sun Tzu² and combine them into an effective strategy. Whether he or she works at a strategic, operational, or tactical level, he is always targeting cognition (cognitive domain) through the manipulation of information (information domain) to cause the

¹ Carl Philipp Gottlieb von Clausewitz (1780 - 1831) was a Prussian soldier and German military theorist who stressed the moral and political aspects of war. His most notable work, *Vom Kriege* (On War), was unfinished at his time of death.

² Sun Tzu (722–481 BC) was an ancient Chinese military general, strategist and philosopher who is traditionally believed, and who is most likely, to have authored the *Art of War*, an influential ancient Chinese book on military strategy.

adversary to take desired actions (physical domain.) From this statement, one can see that information is the weapon, cognition is the target, and actions are the desired effect.

This is how knowledge is created and implemented. Thus, to fully appreciate the power of knowledge people need to understand how information, in any form, affects the way they interact with the environment. Whether the information is a true representation of the environment, a partial truth or outright falsehood is irrelevant. The simple fact that someone receives the information will shape how that person views the situation and subsequently how he or she acts or reacts to his or her environment (i.e., information drives decisions.) In other words, it is how one understands what is going on, and according to one's experience (tacit knowledge) and education-training (explicit knowledge), how one reacts to every trigger.

In the seminal work "Public Opinion," Walter Lippmann identifies the fundamental principles upon which all influence and information operations are based:

The only feeling that anyone can have about an event he does not experience is the feeling aroused by his mental image of the event. Whatever we believe to be a true picture, we treat as if it were the environment itself. When we look closely at our day-to-day lives we discover that there is very little that happens in the world that we personally experience. (Lippman, 1921)

A person's knowledge of what is happening outside of his or her "onboard sensors" comes from second-hand sources. Whether it is a friend relating their experiences, a Facebook posting, a Tweet or a newscast, people are receiving distorted information about events in their world. Whereas Lippmann's work is anecdotal in nature and focuses on how the information one receives shapes his or her knowledge and attitudes, it also provides an excellent approach on how a person's experiences (tacit) and information shapes his or her behavior.

Tacit knowledge (Nonaka, 1994) is deeply rooted in action, commitment, and involvement in a specific context, while explicit knowledge refers to knowledge that is transmittable in a formal, systematic language. There is an abundance of explicit knowledge in the military context such as published general plans and doctrines or other

publications. There is an equal abundance of tacit knowledge within the same context. Developers of information systems obtain tacit knowledge by socializing and internalizing the actions and experiences that they share with militarists and industrialists of the military market. Nissen's *Vertical and Horizontal Processes Model* characterizes the powerful interaction between the flow of work and the flow of knowledge in an enterprise (Nissen, 2002b).

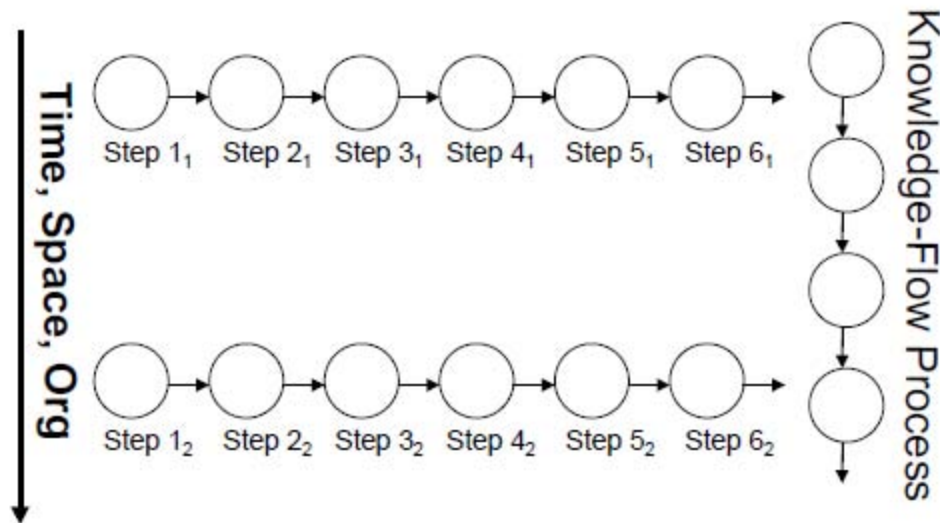


Figure 3. Vertical and Horizontal Process Model (From Nissen, 2002b)

The horizontal, sequential process represents the flow of work, and the vertical process represents the flow of knowledge through time and space. Nissen's dynamic knowledge-flow model conveys the interdependencies of information processing requirements between some tasks in different workflow processes. It assumes that vertical knowledge flow only occurs at the end of a horizontal process and is independent of other workflow processes. However, Nonaka's dynamic theory of organizational knowledge creation posits that knowledge-flow processes—transformation of tacit knowledge to explicit knowledge—occur through socialization, internalization, externalization, and a combination within the individuals of the development team with others, both internal and external, of the organization (Nonaka, 1994).

The author views the transformation of learning into knowledge as a core activity that ultimately results in value embedded in processes that produces results and demonstrates a fundamental connection between learning, knowledge and value. After all, it is not the final destination that gives value to the effort, but the whole process of the trip to reach one's goals. The promise of the Information Age has largely been based on the assumption that current employee knowledge could be redeployed within info-systems and networks to reduce the cost of knowledge use within core processes. Thus, the race for reaching the technological edge that will allow for better, faster and more efficient results has already started. Unfortunately, most of these projects in practice implement information technology (IT) applications such as databases, search engines, and Web portals when attempting to support knowledge management. However, the majority of these applications include the words data or information within their titles; thus, they work at a level that is lower than knowledge, although they are called "knowledge management tools" (Nissen, 2006). Therefore, there is a need to be extremely careful when discussing applications that enhance the flow of knowledge.

D. AGENT-BASED SIMULATION TECHNOLOGY

In today's dynamically unstable environment, the amount of pressure put on government and public service organizations (like the Department of Defense) for maximum performance at the minimum cost is enormous. In order to address these challenges, governments must leverage technology in a way that maximizes efficiency, transparency, and audibility, while providing real-time access to vital information. "Exploiting the benefits of IT, it can be argued that ... technologies automate some activities within workflows but not all of them. The people in an organization perform most workflow roles requiring knowledge-particularly those involving experience, judgment [*decision making*] and like capabilities depend upon tacit knowledge. This leaves IT to largely systematic, clerical, and procedural roles, for which requisite knowledge can be formalized explicitly" (Nissen, 2006, p. 50).

In an effort to analyze the above statement related to processes, it can also be argued that IT systems provide cost-cutting measures, streamline processes, and thereby reduce deficits. The current technological implementations improve crisis response, ensuring that decisions/actions are delivered in a fast and efficient manner.

Supporting this challenging management and learning task is motivation to employ agent-based simulation technology to model and analyze the development process, and thereby seek to improve project performance through enhanced owner-design-construction coordination. Further, such new technology can support the dynamic process of knowledge creation and flow among temporary stakeholders (every participant with an active interest on the project) who do not belong to the project sponsor's organization, but whose combined decisions during the entitlements-feasibility phase impact the facility's overall implementation time and cost. Currently, essential knowledge often remains clumped within specific stakeholders and organizations, as explicit mechanisms such as design specifications and building documents have yet to be developed in this early phase. Thus, the challenges of managing facility development also include organizational learning, which is not understood well in the military domain.

Moreover, people are rationally bounded and limited in their individual and collective abilities to share such knowledge through current means, such as conversations, documents, diagrams, and others.

Nearly all contemporary information systems, instead of addressing the flow of knowledge, are focused on the transfer of information and data, which are qualitatively different across numerous dimensions (Davenport et al., 1998; Teece, 1998). Furthermore, the few theoretical knowledge-flow models that are currently available (Dixon, 2000; Nonaka, 1994) have not yet been developed to a point where they can effectively inform the design of information systems and business processes to enable, automate and support knowledge flow in the enterprise. The current practice shows that such system and process design is accomplished principally by trial and error, which is one of the least-effective design approaches known (Nissen, 2002b). Thus, it is a matter of risk management that needs to be adopted in order to facilitate the benefits of technology with minimum vulnerabilities.

E. RISK MANAGEMENT

Many of the technical efficiencies that make the U.S. so dominant in battle have also made the U.S. very dependent upon their availability, and the disruption of these systems, many of them fully automated, could profoundly degrade combat capabilities. In this respect, information technology is a double-edged sword and one has to proceed carefully. That said, despite the risks it is believed that the benefits are quite great.

Risk is an inherent part of every process, making risk management a vital issue for every organization. By mapping processes with risks and controls, one gets an accurate picture of how an organization operates and how these operations must be improved. Improperly assigned controls and unanticipated risks arise when an organization has a poor understanding of their processes. Thus, a decision-making approach of whether IT in a process enables or transforms is extremely important for the survivability of the process.

Therefore, one has to identify the scope of the process and its gravity to the organization's structure. "Processes that are responsible for the organization (taxonomies, ontologies), the formalization (storing, codifying) and sharing (distribution) of knowledge use the supportive role of the technology focusing on the speed, fidelity and accuracy that an IT system offers as an enabler" (Nissen, 2006, p. 53). Additionally, processes that cover the application (decision-making), refinement (evolution), and creativity exploit the performative role of technology that enhances changes and transforms the working culture.

Therefore, the standardization and consistency of the process that IT provides make it even more tempting. Expert systems technologies (simulation modules) simulate changes to resources and support the effort to avoid costly mistakes by effectively controlling resources. Furthermore, technology provides the supportive means for automatic documentation that ensures the repository of knowledge (key for innovations) and analyzes the processes into logical, small-related steps that set specific goals for achievement. It also provides flexibility and removes redundancies, thus decreasing the time and complexity of actions.

In addition, the performative attributes of IT improve the efficiency and increase the effectiveness of the standard operating procedures by modeling and managing strategies (improved crisis response). Moreover, they formalize rules and policies that influence working behavior and performance. The appropriate technological applications connect government rules to processes, which creates embedded controls within processes, ensures the highest level of governance and compliance highlights potential risks associated with each task, maximizes risk avoidance, and implements standard methodologies.

F. TECHNOLOGY AS A MAJOR ENABLER OR MINOR CONTRIBUTOR OF PROCESSING

Hence, when the process provides only services, then the IT implementation supports the development of this process, offering easy to use solutions that address issues of “what to do” by enforcing the automation, sequential evolution, monitoring, and integration of multifaceted components. On the other hand, when the procedure requires or contains some learning process then the contribution of IT is quite limited for the amelioration of the performance (Nissen, 2006).

Therefore, it is important to identify whether the IT implementation enables or transforms a process. Within the military environment where timely response (time), justifiable investments (money) and intellectual capital (people) are three of the pillars of its structure for successful evolution, IT involvement plays a crucial role in accelerating the processes (time) and improving the performance (people) at the lower cost (money).

Therefore, a certain number of metrics that characterize the figure of merit of these systems that act as major enabler of knowledge management within a military organization is required in order to evaluate them. A representative table with the utility metrics of a military command and control system is seen in Table 5.

Metric Category	Typical Applied Knowledge-Level Metrics	Description
Collection: surveillance and reconnaissance resources required	Collectors required Collection tasking Bandwidth utilization Processing required	Number of collection assets required Loading on collection assets Percent of link bandwidth used Processing resources required
Awareness quality: degree of vigilance and use of all available data	Weapons required Targeting efficiency Sortie generation rate Sorties required Vulnerability	Number and mix of weapons required Percent correct targeting decisions Rate at which sorties can be generated Number of sorties required to achieve objective Degree of vulnerability of assets
C2: command and control utility	OODA cycle time Decision accuracy	Aggregate decision cycle Aggregate command decision accuracy (% correct)

Table 5. Representative Utility Metrics for a Military Command and Control system
(From Waltz, 1998)

Along these same lines, many of the existing tools/systems offer infrastructure support for knowledge work and enhance the environment in which knowledge artifacts are created and managed, but the flow of knowledge itself remains almost indirect. For example, information systems are widely noted as helpful in the virtual office environment (e.g., when geographically-dispersed knowledge workers must collaborate remotely), or by providing networked tools such as shared, indexed and replicated document databases and discussion threads (e.g., Lotus Notes/Domino applications).

These tools serve to mitigate collaboration losses that can arise when rich, face-to-face joint work is not practical or feasible. However, supporting (even rich and remote) communication is not sufficient to guarantee knowledge flow (Nissen, 2002b). The construction and use of knowledge-based systems (KBS) can make knowledge explicit, and thus easier to be transferred within an organization and its application direct, which ensures return on the investment.

G. KNOWLEDGE-BASED SYSTEMS (KBS)

These technologies include applications such as: expert systems and intelligent agents, infrastructure and support tools (e.g., ontologies, inference engines, search algorithms, list and logic programming languages), and a variety of representational formalisms (e.g., rules, frames, scripts, cases, models, semantic networks).

Hence, KBS are predicated on the capture, formalization and application of the core knowledge domain. The use of KBS for knowledge flow within organizations is well known, widespread, and now the subject of textbook applications (Russell & Norvig, 1995; Turban & Aronson, 2001).

The advantage that KBS offer is that they are knowledge itself—not just information or data—and they are designed to interpret and apply represented knowledge directly. These capabilities and features make KBS distinct from most classes of IT applications presently employed for knowledge management (Nissen, 2002b). However, expert system development—through classic knowledge engineering—requires explicit capture and formalization of tacit knowledge possessed by experts. This is just the kind of tacit knowledge that has long been known as being "hard to capture."

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III. THINK-PROCESS-DECIDE-THINK AGAIN

The most incomprehensible thing about the world is that it is comprehensible.

(Albert Einstein)

This chapter provides some basic elements of systems thinking theory, approaching the general idea of mental models and their influence upon the decision-making process. In addition, the author attempts to present some insights on how and what information technology (IT) can do for the support of the decision-making process, which provides some interesting approaches from the military domain.

A. SYSTEMS THINKING THEORY

The review of literature presented that besides the required synergy among the components of a network, feedback and causal loops are key systems thinking concepts or building blocks that follow certain patterns (representative samples) already existing in people's minds. Peter Senge (1990) believes that "Systems' thinking is a conceptual framework, a body of knowledge and tools that has been developed over the past fifty years, to make the full patterns clearer, and to help us see how to change them effectively" (p. 7).

Hence, within that framework, Maritime Interdiction Operations (MIO), a large-scale networking initiative, provides an ideal context for studying since it covers the dynamic behavior of the environment and its participants in addition to the network topology of the system.

According to John Sterman (2000):

If people had a holistic worldview, it is argued, they would then act in consonance with the long-term best interests of the system as a whole, identify the high leverage points in systems, and avoid policy resistance.
(p. 4)

Most human/societal systems are nonlinear feedback systems; therefore, since people are concerned with the behavior of complex systems, system dynamics is grounded in the theory of nonlinear dynamics and feedback controls.

B. AN ACTION LEADS TO REACTION

In the conflict domain of a complex environment, the reciprocal influence between actor and adversary cannot be overstated. Every action engenders a reaction. As one actor acts to alter the state of the system, others may react to restore the balance that was upset, maintaining the dynamic behavior of the whole. Yet, the heuristics one uses to judge causal relations lead systematically to cognitive maps that ignore feedbacks, multiple interconnections, nonlinearities, time delays, and the other elements of dynamic complexity (Abdel-Hamid, 2010).

People tend to use linear—or open-loop—thinking (according to traditional mental behaviors) about a problem that looks like the event/action/result sequence. An event generates an action that sequentially drives to some result. What people tend to miss at that point is the fact that these results are also events that require related actions with follow-on results, and this cycle never ends unless there is a drastic disturbance of the system that will cause the collapse or the total alteration of it.

Each repetition of this cycle adds feedback and dynamics, often with delays. “Delays are a critical source of dynamics in nearly all systems. Some delays breed danger by creating instability and oscillation. Others provide a clearer light by filtering out unwanted variability, and enabling managers to separate signals from noise” (Stermann, 2000, p. 409).

Nonlinear behavior in general complicates the decision-making task, drawing different mental models and courses of action that make the involvement of emerged technology to processes even more demanding. To this end, the introduction of the network-centric concept in military operations became a rather successful approach that addresses the necessity for faster, better and integrated decisions.

C. THE DYNAMIC BEHAVIOR

The challenges that the network-centric approach of the modern armed forces face today, are on how a robustly networked force will lead to improved information sharing, and how this improved information sharing and collaboration will result in improvements in both the quality of information and shared awareness (Alberts & Hayes, 2006). The reason is that the plethora of useless or unused information received by the commanders determines the state of their situational awareness, which sequentially drives them to make proper or false decisions.

There is only limited experience with network-centric concepts and their applications. Thus, while there is a growing body of evidence that network-centric operations can result in dramatic improvements, there are few well-documented quantitative assessments. Further, this network-centric experience is limited to command and control approaches that are fairly traditional (Alberts & Hayes, 2006).

Under the holistic approach of systems thinking theory, one can argue that every decision made or action done can never stay alone, it has to be supported by others and be supportive to others. Thus, in any stage of decision making (including the network-centric environment) one needs some information (feedback) about the results that he/she caused based on his/her actions that will become the basis and the criteria to select his/her future steps.

1. Feedback Loops

The psychologist Powers (1973) wrote:

Feedback is such an all-pervasive and fundamental aspect of behavior that it is as invisible as the air that we breathe. Quite literally it is behavior- we know nothing of our own behavior but the feedback effects of our own outputs. (p. 351)

All dynamics arise from the interaction of just two types of feedback loops: positive or re-enforcing and negative or balancing loops as shown in Figure 4.

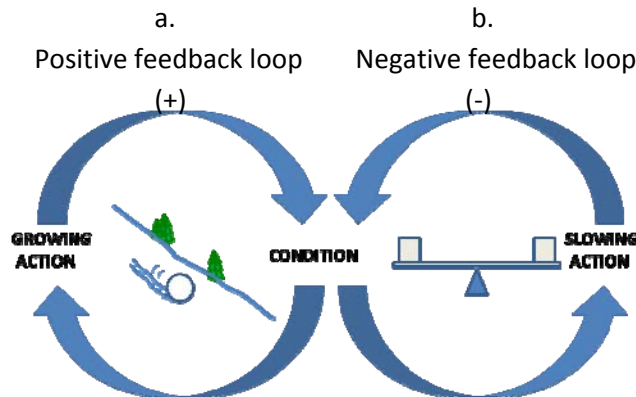


Figure 4. Positive/Negative Feedback Loops (From Senge, 1990)

Positive loops are self-reinforcing (or amplified), meaning that with the interrelation between two agents (entities that are mutually dependent) an initial change is amplified, producing further change in the same direction.

Negative loops are balancing (or self-correcting), meaning that the interrelation between two agents result in the counteraction that opposes the change. Negative feedback loops are different in that they counter and oppose change.

All systems, no matter how complex, consist of networks of positive and negative feedbacks, and all dynamics arise from the interaction of these loops with one another.

Thus, the cognitive nature of feedback loops correlates the entity with the environment that the decision was made in (for example, what is the level of acceptance of the public opinion concerning the scope of the tasks that are included within the MIO framework), or the entity with the scope (i.e., how the MIO commander perceives the reactions of public opinion relative to the MIO activities). Finally, there is the combination of the above, meaning the correlation between the acceptability level of the scope of the mission by the entity in comparison with the acceptability level of public opinion for the necessity of those kinds of activities.

In a similar way as feedback loops, causal loops capture the dependency of the agents that constitute the system under change because of an external (or internal) cause. Thus, when the feedback loops connect the entity with the results of his/her actions that will determine his/her future decisions, the causal loops get into the causality of that result, distinguishing the correlation among the agents (feedback loop) with the reasoning that drove to a specific behavior, attributes, etc. According to J.D. Sterman (2000):

Correlations among variables reflect the past behavior of the system ... do not represent the structure of the system...causal diagrams must include only those relationships you believe capture the underline causal structure of the system. (p. 141)

Hence, it is interesting to examine how these concepts are met in the military domain. Investigators in various fields ranging from psychology to organizational design have noticed that adaptive systems must evolve into more complicated and differentiated structures as they grow in size and operate in increasingly complex environments (Barabasi, 2003). The current profile of military operations fulfills the complexity criteria since it has been largely expanded, covering areas that are far away from the traditional military tasks like peacekeeping operations or humanitarian aid and natural disaster relief.

Like in most of the typical organizations that operate in a complex environment, militaries use a hierarchical system structure with a relatively small number of components to produce a wide variety of different tasks. In a hierarchy, the highest members usually worry about big issues, drawing the lines of the strategic vision while the mid-level managers or commanders in the military “format” take responsibility for particular functions or important sub-goals that their subordinates will undertake in order to serve and support the objectives of the above-mentioned strategic vision (Hayes-Roth, 2006).

For example, while the government and the chiefs of the services under the supervision of the Joint Chief of Staff set the lines of the national strategy, including offensive and defensive goals in addition to armament procurements, the commanders, as mid-level decision-makers, take responsibility for determining how to defend a particular installation, capture a key target, or defeat an enemy unit. At the lowest level of this

organization, individuals, machines, or small ensembles interact with the environment directly and apply resources to transform orders into results that follow the strategic vision's framework.

The hierarchy works both top-down and bottom-up with the military following a combination of the two models. In top-down mode, high-level mission objectives translate into tactics and tasks and ultimately into operations. In bottom-up mode, units measure and report their results, interpretations and lessons learned to superiors, and this process repeats up the levels producing an adaptive decision loop (Hayes-Roth, 2006).

Thus, instead of the traditionally used Boyd's OODA (Observe-Orient-Decide-Act) loop (Figure 5a) that emphasizes four principle steps in adaptive behavior (observe the environment, get oriented towards important factors, decide what to do, and act accordingly), now scholars and managers (including commanders) move to the adaptive decision loop (Figure 5b). This approach requires changing future behavior for achieving better outcomes by reducing differences between the actual results and the initially stated goals.

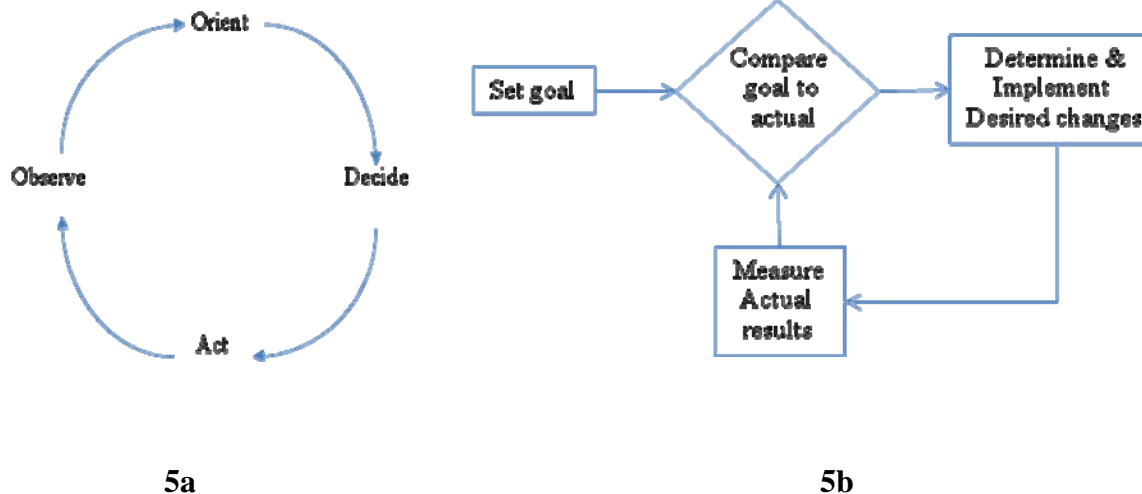


Figure 5. (a) ODDA Loop; (b) Adaptive Decision Loop (From Hayes-Roth, 2006)

Additionally, the commander is an integral part of the command and control system and not just a user of it, and as part of his/her duties has to manage the available information in a timely manner and participating actively in the whole process.

D. TIME IS PRECIOUS

In military operations, time is a precious commodity for three reasons. As one gathers more information in an effort to increase his/her situational awareness (his/her knowledge of the current status and its potential), previously collected information may become obsolete. Additionally, the time that one spends preparing for his/her mission against his/her adversaries, according to the current stage, may alter their plans and change the situation in the process. Finally, the rapid tempo of modern operations forces commanders to make and change decisions based on limited—and sometimes confusing—information emphasizing the race against time. A commander, therefore, must ensure that his/her decision making and execution are swift or at least swifter than those of his/her adversary. Thus, the commander has to address the “principal questions for every delay” that J.D Sterman (2000) introduces: “What is the average length of the delay? What is the distribution of the output around the average delay time?” (p. 412).

E. POORLY PERFORMED DECISION LOOPS

Reality dictates that actual decision loops usually are poorly performing concerning how far the results are from the goals (Hayes-Roth, 2006). The reasons are many, but the author will try to enumerate some of them below.

a) Decision makers receive imperfect, error-prone, incomplete and inconsistent information. There is an unofficial race between the services concerning their effectiveness and professionalism that sometimes makes them not share their information or knowledge of a subject, or when they do they share it they do so partially in order to underline their superiority against the others. On the other hand, in an effort to avoid a potential “penalty” caused by fudged data, they hide their material. Moreover, some time people with low-credibility information “characterize” it as precious in order to gain temporary personal benefits within the organization.

b) Decision makers do not immediately understand situations accurately and are usually very slow to correctly identify little deviations from the scope that drastically

affect the final result. Dissimilar people “translate” differently the same things since they have different educational backgrounds and/or experiences that determine their level of knowledge.

c) Decision makers take a long time to decide how to intervene, and then they usually guess. Most high-level decision makers are distant from the actual battlespace, so the information they receive is aggregated, abstracted, filtered and distorted. Most organizations do not collectively create and operate a comprehensive model of the environment due to the complex and rapid changeability. The personnel chosen to staff rapid-reaction task forces consider some factors ignore some details, and guess, or put more eloquently, try to decide some remedies that would work best.

d) People asked to implement changes rarely understand their tasks and roles perfectly. Instructions usually leave out details under the assumption that the receivers will fill in the missing details in a predictable way. In addition, many tasks and contexts in real life are different than ones extensively planned for and practiced. As a result, requesters usually do not specify tasks adequately, and people receiving tasks have difficulty fully appreciating the nuances of the challenging situations handed to them.

Since there is a huge range of possible results between what an organization actually accomplishes compared to the initially stated goals, any competitor (adversary) that operates decision loops faster, errorless, and with better (more completed) knowledge, more effective communication and more reliable “translation” of goals into actions will gain the competitive advantages that determine the winner of that race.

F. THE PSYCHOLOGY OF THE DECISION MAKERS IN THE MILITARY

The military environment reveals a dynamic organizational structure that varies across different developmental life cycle phases. It is believed that the dynamic nature of this organizational structure can cause knowledge flow breakdown despite the sequential work processes involved (Hayes-Roth, 2006). The author also posits that the high interdependency of tasks in concurrent workflow processes compound such a breakdown. There are also many interdependencies between workflow processes in a military operation. For example, the tactical commander plans with his or her staff and execute

the planning according to his or her operational objectives. At the same time, the supply officers are dealing with the logistics and the overall infrastructure of the enterprise, and the meteo officers (officers responsible for the weather forecast that will affect the operational tempo) provide all the data for the prediction of the environment that supports the goals of the tasks. Thus, there is a need to know how people working in teams make decisions since almost all military operations require the synergy of different services, agencies or people (staff).

For most of the domains, teams are involved, like a helicopter pilot working with a navigator or other helicopter, a navigation officer working with the navigation team of a ship during the berthing process, etc. Thus, the successful ending of any complicated operation will be based on integrated planning that requires the collaboration of many other participants apart from the tactical commander.

G. THE ART OF WAR

The synergistic and multifaceted nature of military operations is enhanced by high uncertainty because despite the sequentially developed activity schedule, each development phase and execution is unique and distinctive, which requires information processing that most of the time cannot be completed.

In addition, conflict termination is determined by humans; humans who must somehow have been persuaded to change their minds about the possibilities of success for their cause. This is where warfare in the information domain meets warfare in the physical domain. For example, if armed forces want someone to abandon his/her course of action in favor of their course of action, they have two options: kill him/her or convince him/her! The true art of war comes in balancing these two to reach our objective.

The research shows that people draw on a large set of abilities that are sources of power. The conventional sources of power include deductive logical thinking, analysis of probabilities, and statistical methods. However, the sources of power that are needed in natural settings are usually not analytical at all, like the power of intuition, mental simulation, metaphor and storytelling (Klein, 1998). The power of intuition enables

someone to size up a situation quickly. The power of mental simulation lets someone imagine how a course of action might be carried out. It is how someone “builds” the final picture of his/her thoughts to be. The power of metaphor lets one draw on his/her experiences by suggesting parallels between the current situation and something else he/she has come across. The power of storytelling helps a person consolidate his/her experiences to make them available in the future, either to him/her or to others (Nissen, 2006). These areas have not been well analyzed by the scholars yet.

Most of the scholars like to study people under pressure relating to time. They have studied chess players under blitz conditions, where the average move was made in six seconds (Klein, 1998). When a component commander makes a poor decision in the battlespace, lives can be lost. Scholars are interested in experienced decision makers since only those who know something about the domain would usually be making high stakes choices. Furthermore, people see experience as a basis for the sources of power they want to understand. They want to know how people carry on even when faced with uncertainty because of inadequate information that may be missing, ambiguous, or unreliable—either because of errors in transmission or deception by an adversary.

Sometimes when one has to make difficult choices, he/she does not fully understand what he/she wants to accomplish. For instance, when fighter pilots are taking off for the interception of unknown radar contacts that have violated national Airspace, they never know the intentions of their targets; thus, they do not know if their mission will end with an actual air battle or a simple recognition procedure. With an ill-defined goal, one is never sure if the decision was right (Klein, 1998). Most tasks are performed within a larger context that includes higher level goals and different tasks with their own requirements, and this must be taken into consideration. Context also includes background conditions, such as noise, poor lighting, constant interruptions, and other stressors that increase the complexity of the decision-making framework.

H. “TA PANTA RHEI (EVERYTHING FLOWS)” (HERACLITUS)

Dynamic conditions (i.e., a changing situation) are an important feature since new information may be received or old information invalidated, and the goals can become

radically transformed. Navy commanders, for example, may have to adapt their decisions for a certain simple task many times per incident. Some changes might be minor and require slight modifications of the decisions, while others might be major and require a shift in the way the commanders understand the situation.

Therefore, one has to identify the following scale of knowledge situations in decision problems that determine the way that he/she decides and acts accordingly (Hansson, 1994):

- Certainty - deterministic knowledge
- Risk - complete probabilistic knowledge
- Uncertainty - partial probabilistic knowledge
- Ignorance - no probabilistic knowledge

It is common to divide decisions into these categories, i.e., decisions "under risk," "under uncertainty," etc. In summary, the standard representation of a decision consists of: (1) a utility matrix and (2) some information about to which degree the various states of nature in that matrix are supposed to obtain. Hence, in the case of decision making under risk, the standard representation includes a probability assignment to each of the states of nature (i.e., to each column in the matrix).

Quite often people tend to choose the first reasonable action they consider. However, in dealing with an adversary who might anticipate one's tendencies, this strategy can get the person in trouble. It leads a person to take typical and therefore predictable actions (Klein, 1998). For example, during anti-submarine warfare exercises between surface ships and submarines, a successful tactic will be for the anti-submarine warfare (ASW) officers of the ships to think how a submariner would think about his/her actions. Perhaps, geological anomalies of the depth or old shipwrecks might be interesting positions for a submarine to hide since they offer recognized and expected coverage by the surface ship crew's sound echoes. The concept is that a strategy can be predictable only against an adversary who actively tries to make predictions and looks ahead. One of the hallmarks of experts is their ability to project current states into the future. The dilemma is that unfortunately most officers will not put themselves in the position of their adversary, but if someone is unlucky enough to come across one who

does, like Alexander the Great and others, then his/her recognitional decision making may get him/her in trouble. In other words, the recognition-primed decision (RPD) strategy is still an accurate description of what people do, but it has this drawback in adversarial situations that call for deception and not typical predictable actions (Klein, Calderwood, & Clinton-Cirocco, 1986).

Skilled commanders have developed an ability to recognize when their courses of action are too obvious. During the evaluation of a plan by mental simulation, the skilled commanders will use a sense of predictability to notice that the adversary can easily anticipate their moves, and they will take the necessary precautions. That characteristic is based on the mental model that these commanders have developed through the years of education, training and experience; it's a combination of learning and talent.

I. MENTAL MODELS

Mental models are representations of reality that people use to understand specific phenomena. Peter Senge (1990) describes them as follows:

Mental models are deeply ingrained assumptions, generalizations, or even pictures or images that influence how we understand the world and how we take action. (p. 8)

Quite often, new insights fail to get put into practice because they conflict with deeply held internal images of how the world works, which are images that limit someone to familiar ways of thinking and deciding. While interacting with the environment, with others, and with the artifacts of technology, people formulate internal, mental models of themselves and of the things with which they are interacting. These models provide predictive and explanatory power for understanding the interaction.

Mental models are so powerful in affecting what one does simply because they affect what he/she sees. It is well accepted that two people with different backgrounds (i.e., mental models) can observe the same event and describe it differently because their “centers of gravity” were different according to what they thought to be more important. As psychologists say, people observe selectively (Senge, 1990).

Since people often remain unaware of their mental models, they remain unexamined and therefore unchanged. As the world changes, the gap widens between mental models and reality, leading to increasingly counterproductive actions.

Each organization needs to develop its capacity to elevate and test the mental models that dominate its decisions. Therefore, in order to address that challenge, there are three facets that are suggested according to P.M. Senge (1990):

- a) Tools that promote personal awareness and reflective skills; b) “Infrastructures” that try to institutionalize regular practice with mental models; and c) A culture that promotes inquiry and challenging our thinking. (p. 171)

The traditional authoritarian organization of the military structure follows the dogma of managing, organizing and controlling, where the new dogma requires vision, values and mental models. Together, openness and merit embody a deep belief that decision-making processes can be transformed if people become more able to surface and discuss productively their different ways of looking at the challenges of today. Of course that approach confronts many objections among the members of military society due to the fact that information and details about an operation are distributed differently at the many levels of the military hierarchy, requiring discipline and task acceptance for the sake of the mission.

MIT’s expert Chris Argyris believes that teams and organizations trap themselves in “defensive routines” that insulate their mental models from examination. Consequently, one develops “skilled incompetence,” which is a great oxymoron to describe being “highly skillful at protecting ourselves from pain and threat posed by learning situations,” but because one fails to learn he/she remains incompetent at producing the results he/she really wants (Argyris, 1995, p. 22).

The ancient Greek philosopher Socrates, and more recently Chris Argyris, both use the obstetrics method, which is called “maieftiki.” This method, combined with the use of irony, was characteristic of Socratic teaching. Under this method, Socrates in discussions was pretending to have complete ignorance on the subject discussed at a time, and through questions was trying to elicit the truth from the interlocutor. Essentially,

Socrates was assuming the role of consciousness and through this process of questions and answers was creating a culture of dialogue in the debate. The interlocutor then replying to these questions and was coming to a conclusion, the “truth” according to Socrates. The method is known as obstetric because the midwife (profession of Fainareti, mother of Socrates) brings the world an infant, and so Socrates or the interlocutor who takes the role of conscience withdraw from the interlocutor of the truth.

Thus, this method can be used for showing one that all he/she ever had are assumptions, and never “truths,” that he/she always sees the world through his/her mental models and that the mental models are always incomplete, and, especially in Western culture, chronically “non-systemic” (Senge, 1990, p. 185). Therefore, one needs to develop skills that assist him/her on building and maintaining his/her mental models.

1. Developing Skills of Reflection and Inquiry Skills

Skills of reflection concern the slowing down of one’s thinking processes so that he/she can become more aware of how he/she forms his/her mental models and the ways they influence his/her actions. Inquiry skills concern how one operates in face-to-face interactions with others, especially in dealing with complex and conflicting issues like those in military operations.

The core of the discipline of mental models consists of the following characteristics:

- a) Facing up to distinctions between what people say and what they actually do;
- b) Recognizing their “habit” of jumping from observation to generalization;
- c) Articulating what the people normally do not say during a discussion with others; and
- d) Balancing inquiry and advocacy, which are the characteristics of charismatic leaders (Senge, 1990).

Since the most crucial mental models in any organization are those shared by key decision makers like commanders, it is essential to work with them in order to improve them. Those models, if unexamined, limit an organization’s quality and quantity of actions to what it is familiar and comfortable with, making all the decisions predictable

and common. Additionally, the commanders ought to develop reflective skills and face-to-face learning skills in order to actively participate in the decisions and actions to be made, or else they will be incapable of being in charge of them. The commander's belief is actually his/her mental model that drives his/her way of thinking and understanding the received information or determining his/her situational awareness.

Systems thinking is equally important to working with mental models effectively. The payoff from integrating systems thinking and mental models will not only be improving of what one thinks but altering his/her way of thinking from models dominated by events to models that recognize changes and their underlying structures. Just as "linear thinking" dominates most mental models used for critical decisions today, the future will force one to make decisions based on shared understandings of interrelationships and patterns of change. Thus, the necessity for supportive technology is imminent due to the complexity and dynamics of the environment.

J. DECISION-MAKING SUPPORT SYSTEMS

Before a decision-making support system can be designed to best optimize human-machine interaction, the problem must be analyzed to determine the nature of the human interactions both from an ecological perspective as well as a user's perspective. The external work environment, namely the system ecology, must be deconstructed and analyzed before the cognitive constraints can be effectively understood and incorporated into a design. To this end, the cognitive work analysis (CWA) approach has been developed to provide cognitive systems engineers with a framework for analysis that identifies not only the user's goals and constraints, but also the impact of the constraints of the environment (Vicente, 1999).

According to this methodology there are five phases of analysis: work domain analysis, control task analysis, analysis of effective strategies, analysis of social and organizational factors, and identification of worker competencies. Emphasizing the primary importance of the environment, the CWA is a tool for understanding how people interact in a particular domain, constraints of both the domain and worker, and tools required in such environments. The end result should be a product in which not only

workers' interactions are understood, but also one in which process relationships relevant to supervisory control and decision making are revealed. Therefore, the same methodology can be applied to process control decision support systems in causal domains as well as intentional domains, including military command and control systems (Burns, Bryant, & Chalmers, 2000).

Intentional domains are human-activity based, as opposed to process control-based, and the goals of intentional systems are organizationally driven and not constrained by the laws of nature. Intentional domains are characterized by time pressured, dynamic problems with a high interdependency of human decisions, which are exactly the characteristics of the majority of military operations that require decisions to be made by commanders.

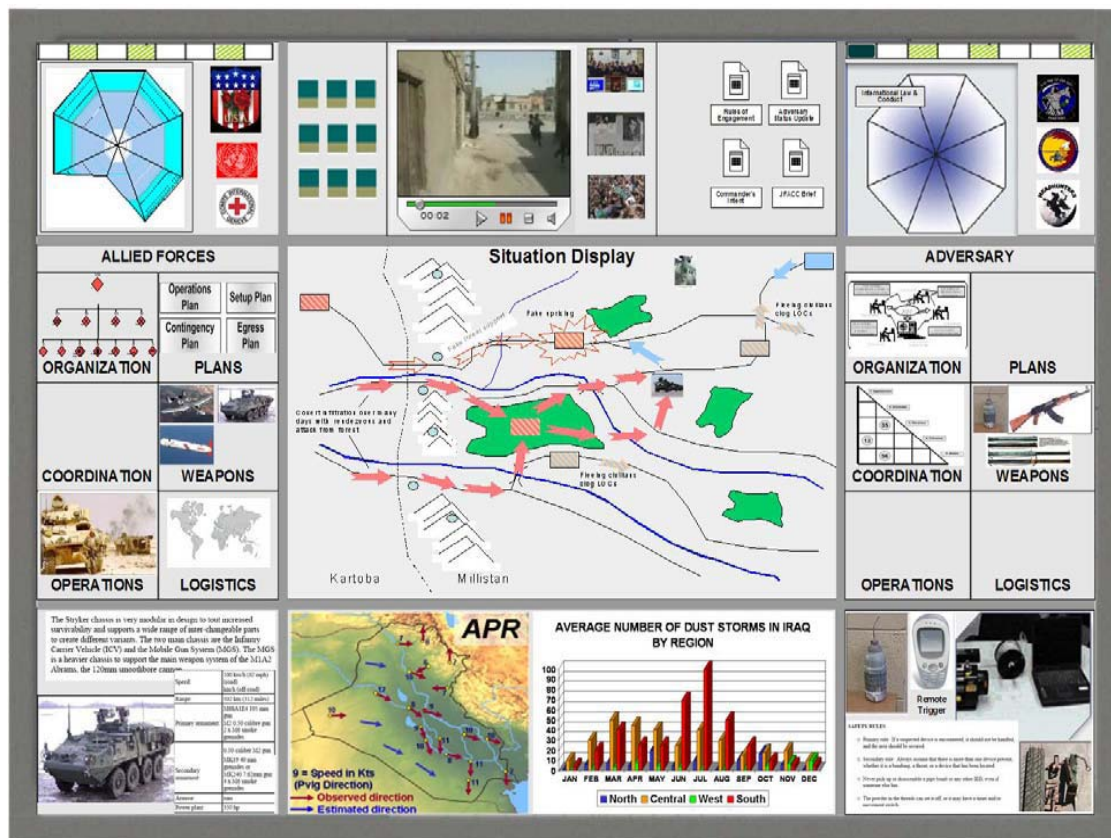


Figure 6. An Ecological Interface for Counter Insurgency Analysis (From Lintern, 2006)

Figure 6 above represents the synthesis of all the appropriate instant data that a decision maker needs when in battlespace in order to maintain the most updated situational awareness that offers the most integrated information for making a decision.

1. Basic Principles

Therefore, understanding the principles will help those using mental models effectively while designing software applications. Some of these principles are the following:

1. **Simplicity.** It is important to keep the design simple to engage and encourage the user to perform a task. For example, according to the system model (designer), an error message would appear as “Error: C5.” Will the user understand this? In most cases, the user probably will not understand this error message. This message should be written as: “There was an error on the printer. Please try again.” This message is simpler and ensures that the user understands.
2. **Familiarity.** The user must be able to relate the task being performed to a real-world scenario. The use of mental models that the user already associates from his/her real-world experience allows him/her to get started quickly and make progress immediately. Labels should not be confusing. People often use the term “folder,” which is from their daily routine. The users are familiar with this metaphor, resulting in easier and effective interaction with the system.
3. **Availability.** Just like in the real world, it is important for an interface to provide visual cues, either automatically or on request. For instance, the user must not be given the chance to search for files or folders. It should be available for every step of the task being performed.
4. **Safety.** The interface should allow a user to easily recover from errors. It is important for him/her to feel confident while performing a task. For example, a user who pays his/her bills online is extremely cautious. During payment, if the page that verifies his/her payment amount is missing, he/she is going to be confused. This confusion happens because in reality people can verify the amount being paid just by cross-checking.
5. **Flexibility.** An interface should support alternative actions that the user can perform during a task. That is, the user should be able to perform the same task in any sequence. It is important to allow him/her to recognize that there are alternative methods. For example, if the user wants to contact a company online, the system image should allow him/her to perform this task either by contacting the company via a toll-free number or through messages from a secure messaging centre available via a website. This is important as the user will feel safe while performing a task, just as he/she will in reality.

6. Feedback. Meaningful feedback at every step is important to strengthen a user's mental model. This should also be a continuous process. People use checklists while they shop for groceries, while they do assignments, or even while they track their expenditures. Along the same lines, providing a checklist while navigating not only allows the user to proceed, but it also matches the mental model of the real world.
7. Affordances. An affordance is a certain property of an object that allows it to perform an action. It is dependent on how a person perceives an object. An interface can have cues to afford how a task can be performed. This can be done by replicating real-world experiences into the interface design. Taking an example from people's day-to-day-lives, they have a certain image of a traffic light signal. Just as the "go" signal affords moving forward, the "go" button affords proceeding further during navigation.

Of course, there are many other factors that influence the designing process of the decision support systems, derived from people's requirements and usage, thus experience, of the terms and systems in reality that constitute their mental model, but the author makes the assumption that these are the most basic ones.

K. AN INTERESTING APPROACH

The DoD has committed to redefine concepts of information superiority and network centric operations and warfare (NCOW) (Hayes-Roth, 2005). FORCEnet³, as an example, attempts to provide the U.S. Navy the capabilities required to support agile, rapid, precise, effective and efficient planning and operations. In these new concepts, warfighters can access and employ whatever information they need to perform their tasks. In short, every person should operate on the right information. One problem, however, is information glut. Too much information is available today, and the problem grows worse over time. Another problem is that people have to work hard to find the valuable information, either because it does not automatically find them or because it is

³ FORCEnet provides critical shared direction, guiding principles, and projected evolutionary objectives for the Navy and Marine Corps' development of future C2 capabilities, to ensure Naval Forces will be ready in the future security environment. The FORCEnet function concept identifies six dimensions of development effort: a) physical (platforms, weapons, sensors, etc.), b) information technology (communications and network infrastructure), c) data (structure and protocols for information handling), d) cognitive (interfaces that support judgment and decision making), e) organizational (new structures and working relationships that will be made possible by FORCEnet), f) operating (new methods and concepts by which forces will accomplish missions with the new, FORCEnet-provided capabilities).

buried amidst megabytes of data and messages that are not important for their particular mission concerns. Thus, information superiority and NCOW depend on enabling each individual to receive valuable information at the right time and, in parallel, the automatic filtering out of low-value information. This requires improved means for allowing the needs of individuals to determine just what information finds them, so they can spend more of their time assessing and acting upon high-value information. This would have the effect of increasing individual productivity throughout the military and, as a consequence, help attain strategic goals. Without such a capability, or even worse, increasing information loads will have the paradoxical effect of reducing mission effectiveness. To solve these problems commanders need a model-based communication network (MCN) that delivers to each of its participants tailored outcomes that satisfy the objectives of “valued information at the right-time (VIRT)” (Hayes-Roth, 2005, p. 3).

The basic VIRT method adapts the information flow around an understanding of mission plans, their rationales or *justifications*, the assumptions and forecasts they depend upon, and their expected outcomes. In short, VIRT looks for information that materially affects expected outcomes and communicates that to decision-makers so they can consider and adopt preferable alternatives in a timely way.

Therefore, the essence of VIRT is that it knows which information handlers really care about what news. Suppliers of information should monitor for a change in their information (news) that would interest operators, because it changes their beliefs about expected outcomes. The final element of VIRT consists of the conveyance employed to transmit the valued news to the user. This should include a means to highlight news in an appropriate way. Preferably, highlighting causes recipients to attend to news with a priority that closely approximates the importance they attribute to it. Urgent and vital information deserves high priority. Unimportant data and stale information deserve low priority. One can employ a range of possible methods to implement the essence of VIRT. In the ideal world, the plans and plan evaluation methods of the operators might be known to the information suppliers. Then, whenever a supplier noticed a change in relevant information, it could “simulate” the operators’ thinking to determine whether the

operators would alter their previously selected plans. In just those cases, it would alert the operators. Otherwise, it would not bother to pass along insignificant changes.

To make VIRT and model-based communication networks routinely available, there is a need to provide some generic capabilities that enable suppliers and consumers of information to understand what information is valuable. These generic capabilities can then be specialized for particular domains of applications and communities of practice, as when weather specialists and aviators establish a shared understanding of concerns such as “enroute icing” and “headwinds.”

VIRT works by seeking significant events in dynamic data sources. To do this, it must understand what significant events undercut assumptions the plan depends on, and how to access and query information sources for the events of interest.

Rather than a specific application, therefore, VIRT architecture aims to provide a generic service for plan monitoring and intelligent filtering of potentially relevant and dynamic information sources. In the generic architecture, the dependency monitor can infer what types of events to look for from any plan whose components include assumptions and a justification. The monitor can also be advised by an operator on how to focus or optimize its functions. VIRT also employs a registry of available information sources to exploit whatever sources become available. VIRT is open to new information suppliers who need only describe what their information sources are and how to access and/or query them. Lastly, the architecture is open on the question of how alerts of significant events should be communicated.

L. SMART PULL-PUSH

Systems designed to produce quality decisions, like VIRT, have many parallels with manufacturing systems. The key to high performance, in both cases, is to produce the most valued products as efficiently as possible. Value reflects the degree to which the products embody superior features and qualities and get to “market” promptly (Hayes-Roth, 2006a).

The DoD is moving to make all information readily locatable, readable, and interpretable (Wolfowitz, 2004) in order to increase the effectiveness and efficiency of the decision makers in the military domain in an effort to decrease the fog of uncertainty and information overload. Therefore, people need to find solutions that can simplify the work imposed upon a decision maker by enabling him/her to express queries in terms of high-level semantic concepts and domain-relevant conditions of interest (COI) and receive complete and valuable responses.

The current technology is trying to develop systems where an operator will be able to ask for all recent reports about a specific subject and the query processor will be able to respond accordingly, employing much knowledge and intelligent reasoning (smart pull). Similarly, if an operator posts a query that is relative to his/her conditions of interest, the agent will be able to filter spatially and temporally relevant reports that provide only the useful and relevant information, thus illustrating a degree of intelligence (smart push) (Hayes-Roth, 2006a).

In particular, these kinds of applications assume that suppliers of information learn what customers actually need to know and provide just that information to them. Intelligent agents, playing the role of information brokers, accept statements from processing entities or operators describing conditions of interest (COIs). These conditions describe potential events that would motivate the operators to change their planned actions to achieve better outcomes. As an example, consider a helicopter pilot intending to fly a particular route in hostile territory. During planning, the pilot plots a low-risk route. Subsequently, new reports about enemy sites and anti-aircraft capabilities along the planned route of flight would match one of the pilot's COIs that update the risk assessment of the initial route, leading to the pilot changing the overall flight plan.

In short, this new technology assumes that many processing entities have a continuous need to know about things that undercut their previous decisions by violating some assumptions on which those decisions depend. Operators engaged in real-time plan execution consider such information vital and urgent. Thus, smart pull-push technology addresses the challenge of getting high-value information quickly to operators who are dependent on it, identifies the required relationship among the customers of the

information that is provided, assures that the operators will give priority to received high-value information, and adapts and achieves better outcomes (Hagel & Laberis, 2010). Therefore, this technology becomes an interesting approach that addresses the problem of the information overload that delays and complicates the decision-making process.

IV. EXPERIMENTING ON MIO

In this chapter the author will attempt to integrate all the previously discussed subjects like dynamic knowledge, knowledge flow and sharing, in addition to feedback loops and their influence on the decision-making process, under the prism of an experiment. Moreover, the author will design and plan an experiment focused on the combination of theoretical knowledge and practical knowing of the participants. Therefore, the planner will present the variables, hypotheses, and criteria that, along with the control mechanisms and fidelity features, constitute the basic pillars of the enterprise.

The motivating factor for this challenge was the author's belief that learning is more productive when it is executed through doing, because this attitude integrates data exchanging that becomes meaningful information, which then in turn generates knowledge under the filter of the existing one. Finally, this interrelation between knowledge and knowing becomes the influential factor for making decisions and thus actions, which will drive to conclusions to be exploited for future development (Nissen, 2006).

A. LEARNING THROUGH DOING

Additionally, according to Dr. Nissen (2006) "Learning refers to knowledge in motion. It is used most often to characterize the creation or acquisition of new knowledge..." (p. 78). On the other hand, "Doing refers to knowledge-based work... [and] ... represents one kind of knowing activity" (Nissen, 2006, p. 73).

Hence, if one would like to test and investigate the significance of his/her knowledge (learning) he/she needs to act (doing) according to a set of hypotheses in a certain environment, experimenting upon selectively manipulated variables.

Therefore, the author will attempt to present an experimentation that shows the intervention and participation of information technology in knowledge sharing, and the improvement of the decision-making process within the MIO (Maritime Interdiction Operation) framework. Moreover, this experimental effort will attempt to address the

issues that both the network manager (for the technical part of the experiment) and the MIO commander (for the tactical part) raise when they have to make decisions that are controversial, either due to the lack of means (equipments, participants), or due to the environment (weather conditions, national and legal restrictions).

B. BACKGROUND MATERIAL

1. Designing the Experiment

a. What Was the Challenge?

There are numerous similar experiments that have been planned and conducted for investigating either the network performance of communication schema in the use of exchanging and forwarding selected data under analysis or the operational difficulties that occur when such operations require multinational participation. However, none of them has dealt with the combination of these aspects, meaning the combined problems that both the MIO commander (at the tactical level) and the network management (at the technical level) confront when they operate in parallel and face the same situation but from a different perspective. Therefore, the challenge was to recognize how knowledge flows and how decisions are made when different national caveats and equipment variations co-exist in a mission that has to be accomplished.

b. Hypothesis (Scenario)

The scenario that is going to be tested consists of two groups of ships (either gunboat class or fast attack crafts) that are geographically dispersed for providing extended area coverage, but also for covering two strategic checkpoints of straits' entrances. This hypothesis tests the challenges that the MIO commander faces when he/she has dispersed units operating simultaneously in no adjacent areas, which means different weather conditions, propagation environment, and different ships' capabilities due to the coalition nature of the force. The last issue raises even more difficulties due to

the fact that different nations have different national caveats while they participate in such operations that drastically increase the difficulty of the commander's decision-making process of solving a "puzzle" of diverse issues.

At this point, whenever a chase of a suspect vessel occurs, the MIO commander requires maintaining direct contact with his/her involved units in action. The tactical problem then is that this situation creates gaps to the coverage that the rest of the force is called to cover by re-arranging the patrolling sectors. However, due to the limited number of ships that is provided for an extended area this situation becomes tactically problematic. In addition, if the chase requires more than two participating units then the problem becomes even worse. Technically, this situation creates problems to the network performance since one or two nodes (units) are forced to sail at the limits or sometimes even outside of their coverage range for their local area network (LAN) requirements. Then, the network manager would request to use other than the involved units to be positioned as relay stations. This decision drastically affects the MIO commander's plans because he/she will have to decide what has the higher priority: the area coverage that might create gaps for illegal actions or the network performance that will provide uninterrupted communication and thus, feedback for further actions to be taken.

The overall scenario becomes even more complicated when it requires the participation of other agencies or subject matter experts (SME) that are located far away from the theater of operations, requiring SATCOM capabilities and other network applications for achieving sufficient communication that will allow for the exchange of data and support the flow of information and knowledge among them.

c. Design or Controlled Variables

A design variable is any quantity or choice directly under the control of the designer of the system, and they are often bounded by constraints and feasibility criteria (Alberts & Hayes, 2006). In other words, design variables are a system's independent variables that define the states of the processes and determine what has to be measured for the optimal management of the system.

The insecurity of wireless links, energy constraints, and the vulnerability of statically configured security schemes have been identified in literature as challenges that characterize mobile ad hoc networks (MANET) like in the case of MIOs. Nevertheless, the single most important feature that differentiates MANET is its dynamic structure and nature, which makes it difficult to be designed under the strict design variable context (Papadimitratos & Haas, 2002).

For the purpose of this research effort, the author will attempt to list a number of such variables that determine the character and the performance of the network.

Design variables	Description	Units
Number of nodes	The total number of small boats, operating boarding teams, relay stations and NOCs participating in the network	Integer number
Clusters	The number of geographically dispersed MIO groups (each group may have 4-5 small boats) that participate in the network	Integer number
Nodes/cluster	The number of nodes per cluster	Integer number
Distance	The max distance between two nodes	n.m
Node's CPU	Each node's processing capability according to the device that it carries	MHz
Antenna gain	Each node's antenna gain	dB
Power status	Power resources for each of the nodes (permanent power supply or rechargeable batteries)	External/Internal
Remaining Power	Each node's power status	Hours
Security level	The node's security clearance	Unclassified(1), confidential(2), restricted(3), secret(4)
Packet loss	Number of packets that were lost during traffic	Percentage
Average throughput	Self-explanatory	Bits/sec
Link quality	The quality received by the end user of a link	Percentage

Table 6. Design Variables

d. Functional Constraints

A constraint is a condition that must be satisfied in order for the design to be feasible. In addition, constraints can reflect resource limitations, user requirements, or objectives set by the end user of the system (Alberts & Hayes, 2006).

At this point, the functional constraints need to be differentiated between the tactical and technical levels. The former address the concerns where the MIO commander has certain limitations to set during the planning and execution of the operations that are based on the safety and security of the participants, as well as other restrictions and caveats set by either the individual nations among the coalition or the higher authority.

The participating units need to gain the MIO commander's trust and appreciation concerning their reliability on accomplishing their mission at the highest level of efficiency and professionalism, which is what the continuous circle of trust represents in Figure 7.

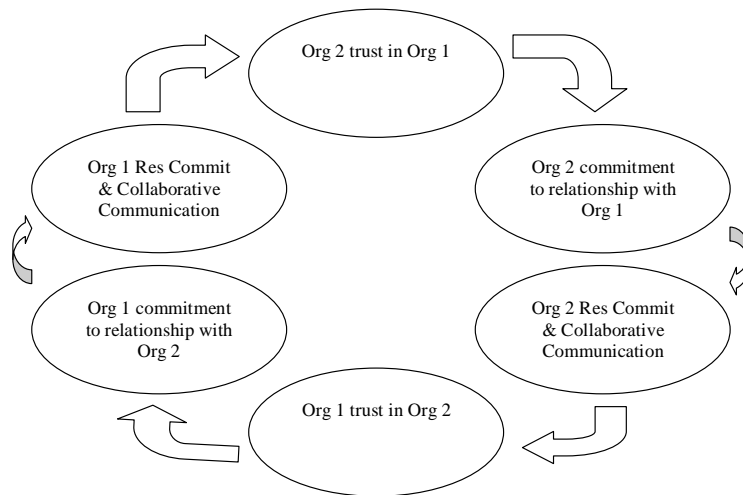


Figure 7. Building Trust (From Hudgens, 2008)

The MIO commander will be able to estimate the situation and set the tactical pattern of the area of operation in conjunction with the proposal set by the network manager, which will be focused on the optimal, and more effective, network structure that extends the performance of the network at the range coverage domain.

Additionally, as mentioned earlier, security issues are always major constraints on any kind of operation with risk management, such as MIO, that expose boarding teams and ships to danger. Thus, weather conditions, common training among the coalition units, and standardization of equipment are some of the factors that the MIO commander has to properly manage in order to extract the appropriate decisions.

Feedback loops ameliorate knowledge sharing among the network participants, which improve the inter-organizational performance of the MIO group for the sake of their mission, thus upgrading their productivity and efficiency.

On the other hand, the dynamic nature of MIO includes potential high-speed chasing of the suspect vessel that consequently requires the quick extension of the MIO mesh network for maintaining the detection process. The result is critical operational constraints associated with tagging, tracking, setting up checkpoints, continuing standoff detection, etc. by means of mesh networking and the situational awareness environment.

For the purposes of this research, the planner will emphasize the functional constraints that constitute quality of service (QoS) metrics (see Table 6) with the assumption that the user's perception of the visible side of the QoS is the definition of the quality of experience (QoE). As Siller and Woods propose (2003), "... [QoE is] the user's perceived experience of what is being presented by the Application Layer, where the application layer acts as a user interface front-end that presents the overall result of the individual Quality of Services" (p. 238).

Functional constrains	Description	Units
Bandwidth	It is a bit rate measure of available or consumed data communication resources	Mbps
Throughput	It is the average rate of successful message delivery over a communication channel	Mbps
Reliability	Provides properties that are related to the delivery of data to different recipients	Percentage
Location awareness	Represents the quality of the provided services relative to the limitations that the location of the nodes produce	High-Medium-Low
Cost	Self-explanatory	Monetary

Table 7. Functional constrains

The key performance factors, which affect throughput and coverage of a network, are presented below in Table 8.

Factor	Dependencies	Impact
Interference	Other devices occupying same frequency spectrum	Impact to SNR (signal-to-noise ratio) – meaning the min. power difference between the required received signal and the noise.
Scattering and multipath fading	Obstacles	Increased transmission errors because of: <ul style="list-style-type: none"> • Decreased power at certain frequencies • The delay spread makes the received signal spread in the time domain
Antenna type	Antenna gain	It is the power gain in comparison to an isotropic antenna measured in isotropic decibels (dBi). Antenna directivity increases antenna gain in a given direction. In client devices, an omni-spherical antenna is most suitable as it allows the device to operate in any position.
	Antenna diversity	Very important in preventing multipath fading, especially for increasing range.
	Antenna cable length	Loss in the cable depends on the length of the cable as cable loss degrades SNR significantly and should be minimized.

Factor	Dependencies	Impact
System design	Receiver sensitivity	The receiver has a minimum received power threshold that the received signal must have to achieve a certain bit rate. If the received signal power is lower than the threshold, the maximum bit rate could be decreased, impacting performance. Receiver sensitivity depends both on RF and baseband design.
	Transmit power	Higher transmit output power provides better performance, but is usually limited by regulatory requirements (e.g., FCC).
	Turnaround time	Time it takes to switch between transmit and receive modes.
Network load	Number of users	Number of users affects performance as the medium is shared.
	Traffic mix	Some applications may be more demanding in terms of bandwidth as compared to others.
Location factor	Distance between access point (AP) and client	As distance between the AP and the client increases, data rate drops.
	Orientation	Performance could be affected by the orientation of the client depending on the location of the antenna and also location of the AP.

Table 8. Key Performance Factors that Affect Throughput and Coverage (From Intel & IBM, 2004)

A rather common functional constraint from either the tactical or the technical aspect of the system is the reliability that both the network has to provide and the participants have to present through their professionalism and dedication to the scope and the mission of the MIO.

e. Effects to Be Measured - Criteria

The criteria matrix will help in narrowing down the feasible solutions of a problem in general, providing the framework within where the solutions fulfill the functional constraints for the total or part of the design variables. Thus, by adapting a

criteria matrix (see Table 9) the planner will be able to determine the importance (weighting factor) of some of the variables, taking into account the goals and objectives of the system.

Criteria	Description	Units
Force effectiveness	Provides the productivity of the force relative to the area of operation, the number of available units and the level of training	Number of incidents that were completed per time unit (day-week-month)
Complexity of task	Determines the level of complication that the specific task requires (i.e., compliant or non compliant boarding etc.)	High-Medium-Low
Time urgency	Presents the level of urgency that the specific mission requires.	Routine-Imminent-Immediate-Urgent
Nature of risk	Determines the level of risk of the operation	High-Medium-Low
Economy of forces	Presents the optimization of the utility of the units	High-Medium-Low
Latency	Determines the minimum acceptable time delay of signal receiving	Time (sec-msec)
Quality of situational awareness	Determines the quality of the information that was gathered relative to the time that was collected and the results that produced	High-Medium-Low
Average throughput	The averaged achieved throughput	Bps
Packet loss	Indicates the “threshold” that we set as acceptable number of packets that might be lost without significantly degrading the quality of the signal	Percentage

Table 9. Criteria Matrix

f. The Pareto Set

The multi-criteria analysis provides the methodology and the techniques for the scrutiny of the components that constitute a system through the holistic approach

of systems theory. Thus, the combination of different variables, constraints and criteria offer a variety of results that determine the area of potential solutions, but not necessarily the most optimal (R. Statnicov, Bordetsky, & A. Statnicov, 2005).

In an effort to optimize the utilization of the feedback loops for efficient management of the system as a whole, the author requires the assistance of the Pareto set. Therefore, the Pareto set as a negotiation set that compromises the design variables, the functional constraints and the criteria in order to determine the optimal solutions is the most appropriate tool. Within that framework, the constant modifications and adjustments of the system underline the ad hoc nature and its dynamic behavior.

In addition, the Pareto optimal solution satisfies the end user's perception of quality, exploiting the mechanism that feedback loops generate by conducting continuous improvements to the process serving the self-organized behavior of the mobile ad hoc networks.

Consequently, the combination of the multi-criteria analysis and the Pareto set makes available to both the MIO commander and network manager supportive tools that improve their decision-making processes and thus ameliorate the performance of the system as a whole, which is the genesis of this research effort.

2. Planning the Experiment

a. Environment

For the purpose of this paper the author selected the geographic area of the Aegean Sea as the environment where the MIO tactical network is deployed, due to its important characteristics. The sensitive nature of this area contains the Southeastern edge of the European Union and the cross-point between the continents of Europe, Asia and Africa where the first is a stabilization factor and the later are significant areas of tension. Thus, the selected environment fulfills the criteria of a checkpoint for the control of the proliferation of weapons of mass destruction (WMD), smuggling, human and drug trafficking, illegal distribution of nuclear products and/or weapons, etc. Within that framework, the exploitation of an adaptive, collaborative tactical network topology

facilitates information and knowledge sharing that improves the decision-making process of the MIO commander. The real-time connectivity between the nodes of the network eliminates the distance between subject matter expert (SME) groups and boarding teams that most of the time conduct and operate at geographically dispersed areas.

b. Tactical and Technical Hierarchical Structure

In an attempt to briefly present the hierarchical structure of MIO from the tactical-organizational point of view, the following tree diagram underlines the tactical relationships among the participants of the network.

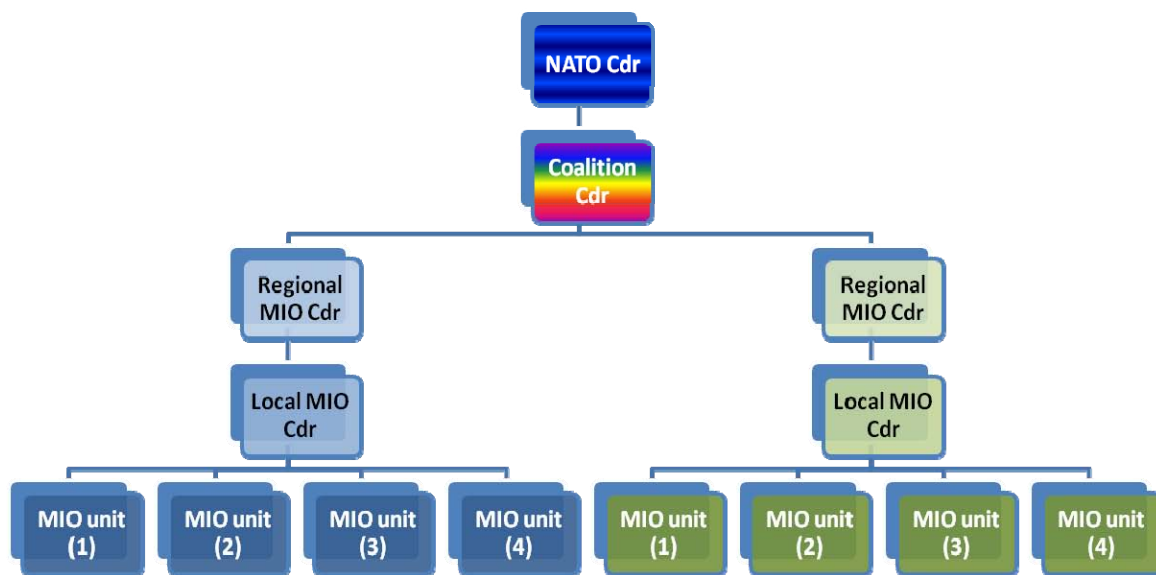


Figure 8. Tactical Hierarchy of the MIO Structure

In addition, each one of the MIO units has to comply with national rules and restrictions to the mission that reflect national policy on sensitive issues related to international and public diplomacy or bilateral agreements.

On the other hand, the topology of the network demonstrates its hierarchy, like the following example where the NOCs (network operation centers) represent hubs that monitor the traffic and collect, analyze, and process the data in order to maintain uninterrupted and high-quality services.

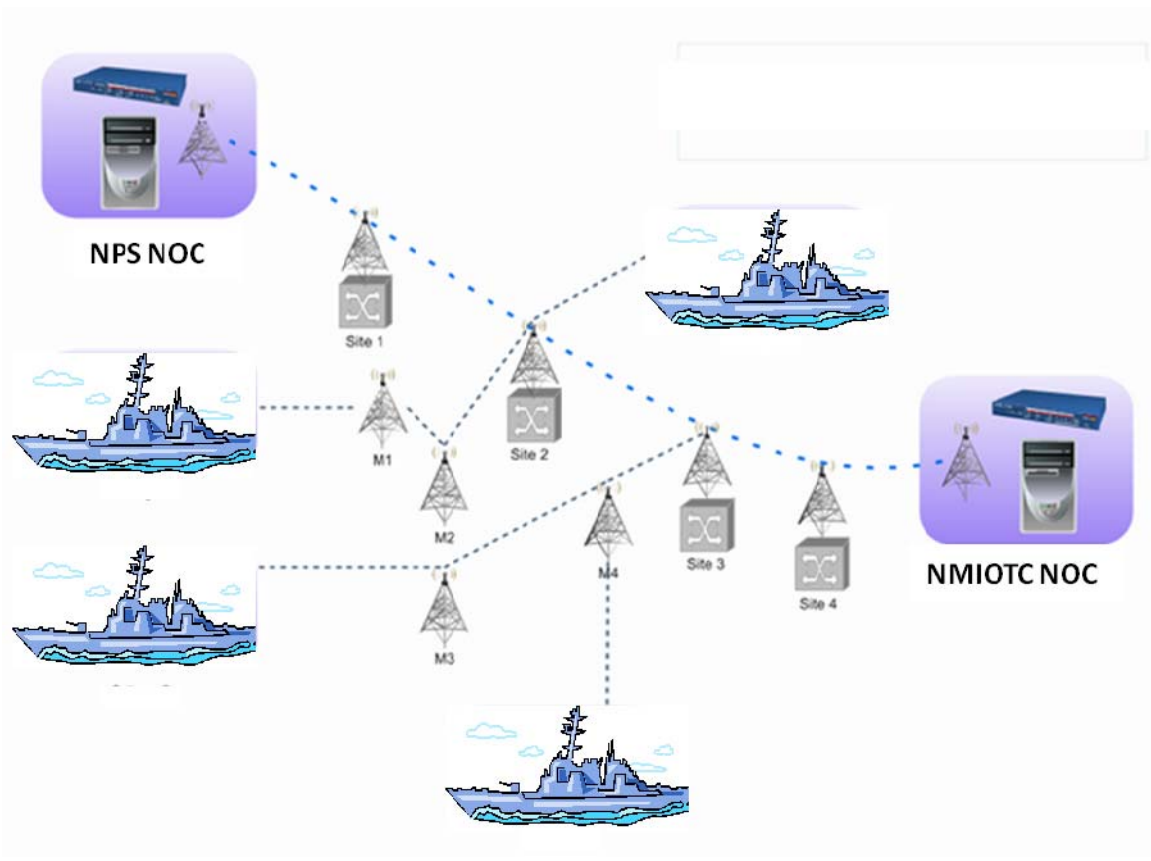


Figure 9. MIO Network Topology

c. Network Components and Relationships

The building blocks consist of nodes that are comprised of various individuals (local authorities, Coast Guard representatives, ship owners, etc.), teams (boarding teams, “mothership” crews, staff officers, etc.), and organizations (civilian, military). The links are defined as communication channels that are connected for a particular duration of time, utilizing a particular technology platform, and may be

counted in terms of the number present in an adaptive network topology over a particular period of time (Bordetsky, R. Bergin, & Y. Bergin, 2009).

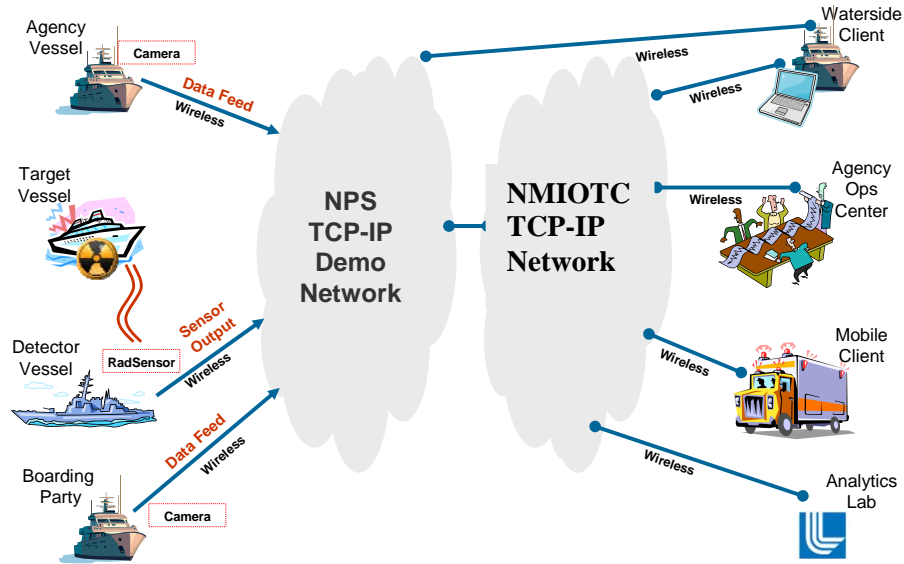


Figure 10. Radiological Interdiction and Command Center Communications (After Bordetsky et al., 2009)

Therefore, according to the above figure, the planner can maintain two NOCs, one at the Naval Postgraduate School (NPS) and another one locally positioned at the NATO Maritime Interdiction Operation Training Center (NMIOTC) in Suda Bay, Crete, Greece. The two NOCs are interconnected in order to exchange real-time information for the sake of building integrated recognized maritime pictures (RMP) that exploit the assistance of subject matter experts that are stationed many thousands miles away from the theater of operations. Upon completion of the environmental settings of the experiment the planner needs to set the parameters that govern the model.

d. System's Description

The experimental model's network framework consists of two clusters of nodes where each node is a naval unit and each cluster is a group of three to four of the units that operate in a specific geographic area and create two independent local area

networks (LANs). Thus, each LAN has its own LAN manager responsible for the connectivity and quality of service (QoS) that is provided among the participants, meaning ship to ship or ship to shore or ship to boarding teams' communications, etc. Both of the LANs are connected and exchanging data with the land-based headquarters located at the NATO Maritime Interdiction Operations Training Center (NMIOTC) in Crete, Greece. The local authorities, the RadHaz (Radiation Hazard) experts, etc. constitute a LAN under the control of the LAN manager of the NMIOTC who also acts as the wide area network (WAN) manager, monitoring and controlling the subordinate clusters of the naval units that operate under the NMIOTC's command. Then, this land-based cluster will be directly connected through SATCOM (Satellite Communications) links with another cluster that contains all the required participants at the NPS according to the existing experience gained by the tactical network topology/MIO (TNT/MIO) series of experimentation (Bordetsky, Dougan, & Nekoogar, 2006).

Figure 11 provides the topology of the discovery experiment as it has been explicitly presented.

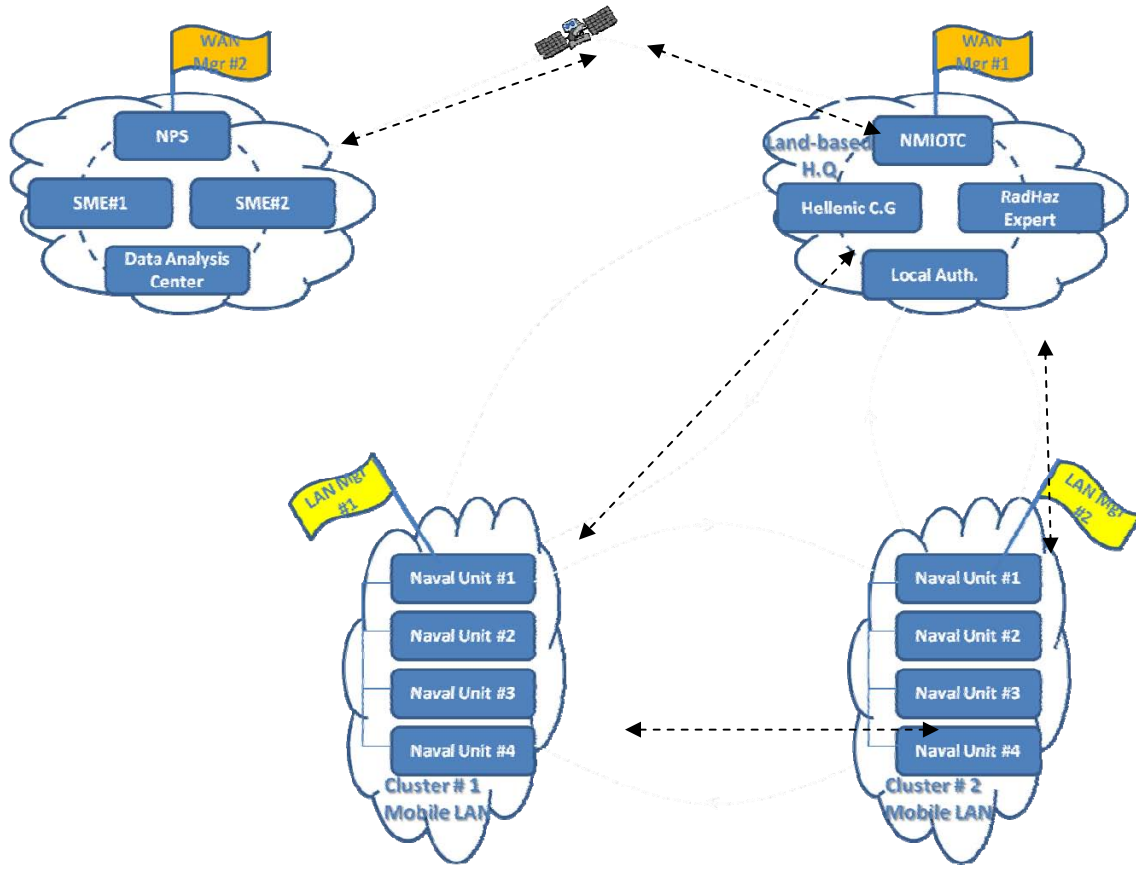


Figure 11. Discovery Experimentation Topology

At that point, it is essential to differentiate the technical part of the experiment from the tactical one, where the organizational structure of the MIO hierarchy, as it has been presented earlier in this paper, determines the relationships and the chain of command among the participants of the system as a whole.

As already stated, the goal is the identification of the proper feedback loops, which can help the network performance within the spectrum of the functional constraints by operating in the best way. Thus, the processed information will be shared with the potential generation of new knowledge that eventually will flow among the participants of the network. Consequently, the flow of knowledge will affect the decision-making process, which is the requirement at the tactical and technical domain of this experiment.

At this stage, the establishment of a well-bounded experimentation routine and the determination of a clearly defined set of requirements in the pre-experimentation phase will allow the planners to identify any issues early enough and avoid any latter inconvenience.

e. Hypothesis Testing Experiments

The generation of hypothesis scenarios moves the author to the hypothesis testing phase of the campaign of experimentation, where the planners of the experiment will be able to discover the limiting conditions and/or test a proposed theory within the framework of the design variables (independent) under the prism of the functional constraints (dependent) and the criteria set (control mechanisms). Through the “if...then” method they will be able to isolate any factor of interest and test it, producing new knowledge based on the observed behavior of that factor.

The hypothesis testing experiments are formulated through the control and manipulation of the factors of interest.

For the purposes of this experiment, an example of the “if...then...when...” technique would be the following:

(1) Operational Approach. **If** information sharing occurs **then** group situational awareness increases **when** the scope and the mission of the MIO is clearly defined by the upper level of command and understood by all lower levels of participants. In addition,

If all participants contribute evenly and continuously **then** the sufficient coverage of the area of responsibility increases **when** coalition members and organizations share the same feelings about the importance of the MIO mission.

Through the above statements, one can clearly recognize the hierarchical relationship among the members of the MIO system and the role that the feedback loops play in the building of the shared situational awareness among the participants of the network. Moreover, it is required for the successful evolution of the operations that all the participants maintain a shared vision of the scope and objectives of the mission.

(2) Technical Approach. **If** data exchange is conducted without any interruption **then** network performance increases **when** the bandwidth and its related throughput are sufficient enough to allow the continuous data traffic.

Furthermore, if the number of nodes per cluster increases **then** network performance increases **when** the nodes are equipped with similar and compatible technology that provides more alternative routing paths and handles any failure incident more effectively. At that time the causal loops provide the data that is required for maintaining or even increasing the quality of service in order to ameliorate the network performance.

The specific goal of the campaign of experimentation will be to explore and exploit the impact of the causal loops on network performance. To this end, the planners are looking for networking and situational awareness solutions for interdicting, searching, tagging, and monitoring large vessels or small crafts that can threaten the security of the coastal areas, or be part of a transition network of the illegal distribution of radiological, nuclear, chemical or other subsequent products in an effort to eliminate any terrorist activity in the vicinity of the Eastern Mediterranean.

The situational awareness goals of the experiment is the exploitation of any feedback mechanism capable of increasing the broad interagency collaboration and information sharing, using the existing capabilities of the naval and land-based units that participate in the network. In addition, the involvement of SATCOM technology will give planners the flexibility of extending the local capabilities, which will provide a universal profile by connecting the NMIOTC and the adjacent organizations and authorities with subject matter experts and other related agencies located across the ocean.

These feedback loops can be achieved with the establishment of two-way data sharing techniques like the CENETIXS SA⁴ Observer Notebook or the Office Groovy⁵ tool, which can both build a common recognized maritime picture (RMP) that collects and exchanges data that can be analyzed and produces information based on

⁴ CENETIXS SA: NPS's Center for Network Innovation and Experimentation Situation Awareness.

⁵ For more information, see the official site of Microsoft.

the explicit and tacit knowledge of the participants. Sequentially, that information might generate new knowledge upon the techniques or the means that the potential terrorists use in order to be distributed among the collaborating agencies of the network ameliorating their shared situational awareness.

Additionally, the real-time exchange of data and information can be achieved by the implementation of video streaming technology using any video teleconferencing facility that connects instantly and more interactively the participants of the network. Another equally useful tool that was successfully implemented at the CENETIXS labs is the situation awareness (SA) viewer,⁶ where alarms and messages can be exchanged and presented on the actual locations that are produced through the collaboration with the Google Earth applications.

All the solutions mentioned above can easily be exploited either at a local level, meaning among the members of each one of the clusters that constitute the under experimentation network, or between nodes from different clusters, or even from the system as a whole. With all that in mind, one can maintain not only the shared situational awareness but also monitor and control the behavior of the network at each of its stages: locally, regionally, and globally.

Furthermore, network monitoring tools like SolarWinds⁷, DopplerView⁸ and others in conjunction with the above-mentioned collaborative systems can enhance any network management decision model implemented to support the quality of service standards.

Most network management architectures use a similar basic structure and set of relationships among their agents. End stations (managed devices), such as computer systems and other network devices, run software that enables them to send alerts when they recognize any kind of fault or configuration problems (for example, when one or more user-determined thresholds are exceeded). Upon receiving these alerts,

⁶ More information can be received through the official site of CENETIX/NPS (<http://cenetix.nps.edu/cenetix>)

⁷ More information can be received from the official site (www.solarwinds.com)

⁸ More information can be received from the official site (www.kratosnetworks.com)

network monitoring tools are programmed to react by executing a series of actions, including operator notification, event logging, system shutdown, and automatic attempts at system repair.

Management entities can also poll end stations to check the values of certain variables. Polling can be automatic or user initiated, but agents in the managed devices respond to all polls. According to Cisco's "Internetworking technology handbook," the agents are software modules that first compile information about the managed devices in which they reside, then store this information in a management database, and finally provide it (proactively or reactively) to management entities within network management systems (NMSs) via a network management protocol (Cisco, 2009).

Well-known network management protocols include the Simple Network Management Protocol (SNMP) and Common Management Information Protocol (CMIP) (Subramanian, 2000). Management proxies are entities that provide management information on behalf of other entities. Figure 12 depicts a typical network management architecture.

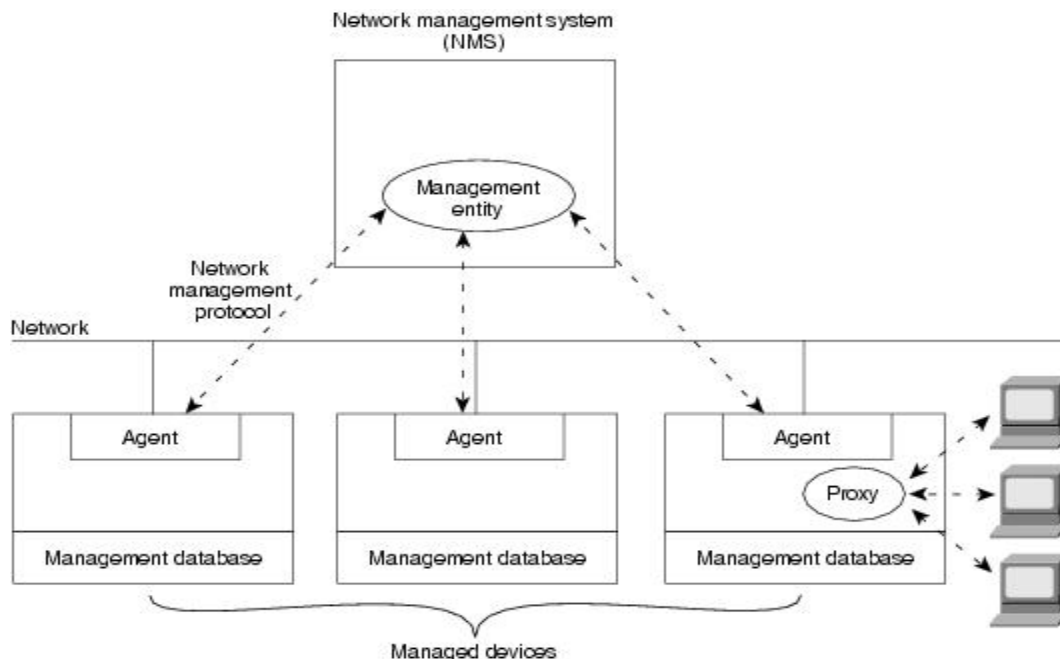


Figure 12. Typical Network Management Architecture Maintains Many Relationships
(From Cisco, 2009)

Within the spectrum of this experiment and for the constraints' analysis phase of the experiment, the author has to make a number of assumptions based on the measures of the reach-back's performance, the MIO collaborative behavior and the network performance as a whole.

Following are some of the parameters:

- Ability of the boarding party to maintain connectivity with their mother ship and/or the local and regional commander.
- Speed and accuracy of the radiation detection analyses.
- Access time for mobile units (boarding teams) and synchronization with all sites.
- Time and feasibility considering the mobile nature of the target.
- Reliability and quality of experience that determines the received quality of the video (remote site observation).
- Rapid decision-making process, which is required for the boarding party members in order to proceed to the next step in the process.
- All team members have sufficient knowledge and familiarity with the employed technology that eliminates time issues when dealing with complex situations and developing common SA among the participants. These technologies include ultra wide band (UWB) communications for exchanging data files and pictures, as well as any other received evidence (radiation detection material) for overcoming any shortcomings of the narrowband communications systems in heavy metallic environments inside ships.
- Ability to establish reliable mesh-links (ship to ship and ship to shore) by all participants.
- Recognizing performance variations as a function of geography, geometry, range and electronic interference environment due to the uniqueness on the structure of the small naval units.

According to Hazen (2003), the key problem in modeling the war-fighting effectiveness of applications (network centric or not) lies in linking the local effects of the application to engagement/scenario measures of effectiveness. Thus, the role of the feedback loops operationally, and the causal loops technically, under certain

conditions and functional constraints determined by the environment and the nature of the mission in addition to the coalition profile of the participants (resulting the variation on the device standardization), underlines their necessity to the overall performance of the network as a system.

The following two-stage approach is required:

1. Determine the local effects of the application on “engagement” parameters by calculating measures of performance (MOP) for the application
2. Use an appropriate engagement model to link the MOP inputs to engagement/scenario measures of effectiveness (MOE).

When systems are vaguely understood, analysis is often conducted by starting with a parametric evaluation of stage two in order to develop an understanding of the warfare operation. The understanding thus developed can then be used to suggest and develop specific concepts or equipment (Hazen, 2003).

3. Demonstration Experiment

The testbed contains an expanding set of domestic and overseas remote command and tactical centers with global reach-back capabilities and rapidly deployable self-forming wireless clusters. From the systems theory standpoint, the NPS-TNT testbed (which gathers many similarities with the proposed experiment) represents a unique research service of social and information networking. It provides for the adaptation and integration of processes between people, networks, sensors, and unmanned systems (Bordetsky, Dougan, & Nekoogar, 2006).

Upon the completion of this experimentation process, a demonstration of the knowledge that has been created, based on the results that the planners and executers received from the causal effects of the network, will prove the validity and credibility of the initially stated assumptions within the framework of the existing hypothesis tests.

4. Define Fidelity and Control Balance of the Experiment

a. Fidelity Criteria

Fidelity measurement has increasing significance for evaluation, treatment effectiveness research, and service administration. The dynamic nature of fidelity criteria, their appropriate validation and statistical analysis methods, along with the inclusion of structure and process criteria in the fidelity assessment, has a significant gravity for the validity and credibility of both the experiment and its results. Further attention to the use and refinement of fidelity criteria is important to the evaluation practice (Mowbray, Holter, Teague, & Bybee, 2003).

For the purposes of this experiment, some of the fidelity issues that the planners have to consider are the following:

- Scenario background details within the framework of the current operations.
- The expected quality applications from the end users.
- The level of collaboration among the different participating units.
- The selection criteria for the team composition of the system.
- Networking capabilities of the geographically dispersed units.
- Bandwidth requirements for tactical operations with respect to the realism of the geography of the experiment and the number of participating units.
- Reliability and bandwidth constraints of communication links among the units.
- The quality of experience that characterizes the subject matter experts who are responsible for the analysis of the data and contribute to the decision-making process.

b. Control Mechanisms

The proposed optimal solution will have to introduce sufficient network management through the utilization of feedback loops, maximizing the overall performance in terms of connectivity and quality of the network as a whole. Throughout the experimentation process there is a big trade-off between openness that mobile agents

offer and security and safety, which are highly appreciated issues especially within the military environment that embraces MIO missions as well.

Therefore, a series of control mechanisms is required to ensure the validity, credibility and reliability of the experiment, setting the boundaries through which the planners will manipulate the appropriate design variables (independent) within the framework of the functional constraints (dependent) under the prism of the optimization criteria.

An approach of defining those mechanisms would be the listing of all the restrictions that apply to the operational environment, like the different national caveats that each of the participating nations within the coalition have or the operational limitations of the participants due to the variation of the type and capabilities of the units. Furthermore, the quality of the provided services relative to the limitations that the location of the nodes produces, in addition to the cost and logistics management of the operation, determine the control mechanisms' network. Thus, the efficiency and the effectiveness of any MIO mission are dependent upon these variables.

Similarly, the throughput capacity of the communication channel and the network's load can provide the metrics of the network's performance according to the number of participants and the level of the quality of service.

C. EXPERIMENTATION SUMMARY

The existing literature and experimentation history that is related to MIO describes and analyzes the behavior of the network from its technical aspect. In addition, the military doctrines recognize the difficulties of such operations and determine certain procedures for the successful completion of them. However, many times the requirements set by the network manager in order to achieve and maintain a high level of network performance are outside of the operational boundaries of the MIO commander. Furthermore, there are certain circumstances where the MIO commander requires the extension of the mesh network (i.e., during the chasing of a suspect) without the ability to add more units, thus nodes, to the network as a whole. Therefore, neither the prior nor the latter can achieve the highest of their expectations for the accomplishment of their duties.

Thus, the objective of this proposed campaign of experimentation is to combine these two collaborative domains, the tactical/operational and the technical, for the amelioration of network performance handling the system as an integrated entity.

In addition, the increased shared situational awareness and the knowledge flow will assure the improvement of the decision-making process for both the MIO commander and the network manager.

The author believes that a potential change in the working culture might be a good start, in order for the MIO commander and the network manager to understand the difficulties and the idiosyncrasies that both of them face from a different approach, every time that they have to cooperate under the same scope but with different (and sometimes controversial) supportive means.

The necessity for uninterrupted and reliable exchange of data among all the participants will provide the ability for processing information that SMEs can upgrade due to their knowledge and experience. Thus, generating knowledge will result in more knowledgeable personnel, which will improve the performance of all the participants at the tactical level supporting the decision-making process of the MIO commander. In addition, it will also improve the network performance, due to the fact that better cooperation increases the efficiency and effectiveness of the network.

V. CONCLUSIONS

As the final chapter of this research effort the author will attempt to present a number of conclusions that are derived either from the literature review of the dynamic knowledge and decision-making realms or from the expected results of technical/tactical experimentations that test and investigate the interrelation between knowledge and decisions within the military environment of MIO. Furthermore, the author will emphasize the role that IT plays in the decision-making process in an effort to trigger the interest of the reader for further research

Information systems' technology plays an increasingly important role in the processes that add value to raw materials, whether they are in the traditional sense animal, mineral, vegetable, or even ideas (Hayes-Roth, 2006).

Wealth and power have always been closely interrelated, with significant capital being necessary to obtain the instruments of power (weapons and armies). Today's world is, in some ways, a far more dangerous place because more players can afford the investments needed for weapons of mass destruction (WMD) and terror. The affordability of WMD is reaching a level where they are no longer the exclusive property of nation states. They can now be increasingly found in the arsenals of terrorists, financed by rogue states or even wealthy individuals.

The advent of information systems that support the decision-making process exacerbates the problem. The tools and techniques of information wars are even less expensive and more widely available than the traditional WMD. Moreover, the havoc they could wreak is not yet fully understood. Imagine what would happen if tanks, planes, ships, and munitions could be copied and distributed like software. The platforms and weapons of information warfare can.

Information technologies have proven to be revolutionary not only in the nature of the capabilities being developed in the information domain and the pace of these advances, but also in promoting discontinuous changes in the way individuals and organizations create effects, accomplish their tasks, and realize their objectives, thus, creating knowledge that requires some form of action.

Information gathering, analysis, and decision making are activities on the critical path of one's actions. Advances in information age concepts and technologies are compressing that process cycle time. These changes in the dimensions of time and space are increasing the pace of events, or operating tempo, in many different environments.

A commander who makes and implements sound decisions faster than his/her adversary, while operating within his/her opponent's decision and execution cycle, increases the relative tempo of operations and leverages his/her capabilities in maneuverability and firepower. In time, this ever-increasing advantage in relative combat power can prove decisive. Revolutionary advances in the technologies of surveillance, communications, information processing, and weapon systems are increasing the pace and reach of warfare exponentially. Future warfare will take place in an expanded battlespace, characterized by rapid, simultaneous, and violent actions across all dimensions—air, land, sea, undersea, space, time, and the electromagnetic spectrum.

A commander is connected to his/her subordinate commanders by a command and control system that collects, processes, disseminates, and protects information. Additionally, the commanders use information to support decision making and, through subordinate commanders, extend their dominance over the forces of the adversary. Despite today's complex infrastructure of systems and technology, command is inherently an intensely human activity. The element of personal leadership in naval command, for instance, never should be discounted.

Moreover, a commander commands by deciding what must be done and exercising leadership to inspire subordinates toward a common goal; he/she controls by monitoring and influencing the action(s) required to accomplish what must be done.

Feedback is a vital element of control, as it gives the commander a way to monitor events, adapt to changing circumstances, adjust the allocation of resources, and harmonize the efforts of the force; thus, it improves his/her initial decisions.

The research described in this paper builds upon and extends current theory pertaining to knowledge flow and focuses, in particular, on investigating its dynamics to inform the design of information systems and business processes. In addition, the author provides some of the already existing applications (VIRT, ForceNet) and/or proposed architectures (Smart Pull/Push) in an effort to trigger the interest of the reader for further research and potential discovery of the most suitable for his/her scope applications.

In today's demanding military environment the key to success is to know first, and therefore act first and best protect one's interests while being able to manipulate the adversaries' decisions. Highly placed decision makers around the globe have noted the greatly increased pressures upon them to react quickly to breaking events, often first finding out about these potential crises, not from their traditional sources, but from the news media. It is ironic that the information age, which on one hand provides vastly increased capabilities of collecting and processing data that makes it possible to make better decisions more quickly, is—on the other hand—reduces the time available to make decisions. Thus, the race is on. People need to either find ways to respond more quickly with quality decisions or find ways to extend the time for critical decisions by expediting other parts of the process. Technology provides proposals for potential supportive solutions. Whoever gets behind this race loses the game of competitive advantage.

From now on, our digital infrastructure, the networks and computers we depend on every day should be treated as a strategic national asset that adds value to our intellectual capital. (White House, May 2010)

Future commanders and directors need to have both the technical capability and the ability to communicate issues like cyber warfare and information dominance so that people understand and have trust and confidence that the gained knowledge and strategic vision of a nation is properly handled and correctly managed. Because cybersecurity is a fairly new concern, there is little known about what would constitute a 'cyber war'. One

of the critical realities that come with cybersecurity is how extensively the cyber domain and the physical world intersect, and what the consequences can be to national security if officials are ill-prepared for an attack.

Today, one of the bigger challenges is to find ways to make the work factor for an attack by sophisticated adversaries much larger, thus tipping the scales in favor of the defender through robust, resilient systems built on a solid foundation and that can support dynamic defense.

As the tactics and capabilities of potential adversaries evolve beyond the traditional battlefield, the military should remain vigilant in maintaining an information edge through education, training and awareness in the information superiority fields that will drive that vigilance. The struggle for operational advantage will be an ongoing one, with enemies and strategies constantly changing. The one certainty is that there will be no turning back for the commitment of the military to maintain dominance in the information domain.

Drawing on Leavitt (1965) and others, new IT needs to be integrated with the design of the process it supports. That is, the organization, people, procedures, culture and other key factors need to be considered in addition to technology. Given that many knowledge management projects now revolve around IT implementation (e.g., intranets/extranets, Web portals, groupware) (Nissen et al., 2000), re-engineering and knowledge management even appear to be sharing some of the same mistakes.

For the naval commander, naval intelligence is a form of knowledge that helps build a picture of the situation as it exists now and how it may exist in the future. As people gain knowledge they begin to see the relationships between events in the battlespace, fathom the way an enemy thinks, and project what he/she might do. More importantly, at this level people begin to recognize some of the things that will forever remain unknown, and thus identify the uncertainty they must deal with. However, in general, the lower the echelon of command, the faster and more direct decision making can be. An individual unit commander can normally base decisions on factors that he/she observes firsthand. At successively higher echelons of command, commanders are further

removed from events by time and distance. Consequentially, in a well-trained force imbued with initiative, the lower that the decision-making threshold can be pushed, the swifter the decision and execution cycle will become.

Successfully conducting operations requires access to information available outside the operational area. Information infrastructures no longer parallel traditional command lines, and war-fighters need frequent, instant, and reliable access to information at their headquarters as well as in theater. Mobility and sustainment of forces are highly dependent on commercial infrastructures that include international telecommunications, the public switched network, commercial satellites and ground stations, transportation systems, and electric power grids. Joint forces require secure video teleconferencing; data base connectivity, direct downlink, and broadcast/receive capabilities for reachback access to intelligence, logistics, and other essential support data. The technical complexity and management of these information infrastructures could inhibit a commander's ability to control the flow of information or dynamically manage available information and telecommunications resources (JP-3-13).

The networking of knowledgeable entities enables them to share information and collaborate to develop shared awareness, and also to collaborate with one another to achieve a degree of self-synchronization. The net result is increased combat power. For example, the principle of 'on the offensive' is to act rather than react and to dictate the time, place, purpose, scope, intensity, and pace of operations. This is all about battlespace awareness, speed of command, and responsiveness. The application of network-centric concepts has enormous potential for improving people's ability to achieve battlespace awareness, speed of command, and force responsiveness.

While predicting human and organizational behavior will remain well beyond the state of the art, having a better near real-time picture of what is happening (in situations where this is possible from observing things that move, emit, etc.) certainly reduces uncertainty in a meaningful way. The author would argue that better battlespace awareness and increased responsiveness could help people shape the battle to their advantage.

It is really about exploiting information to maximize combat power by bringing more of the available information and war-fighting assets to collaborate, both effectively and efficiently. Thus, the development of collaborative working environments for commanders and for all war-fighters (soldiers, sailors, and airmen) will make it easier to develop common perceptions of the situation and achieve self-coordinated responses to a variety of complex situations. Therefore, there is definitely a challenge for automated tools and decision aids on the battlespaces of the future. There are different types of decisions to be made, and different tools and approaches to these decisions are appropriate.

Across a broad range of activities and operations, the time required by individuals to access or collect the information relevant to a decision or action has been reduced by orders of magnitude, while the volume of information that can be accessed has increased exponentially. Consequently, across a broad range of value-creating activities, the fundamental limits to the velocity of operations are no longer governed by space or time. Instead, the fundamental limits are governed by the act of deciding, by the firings of neurons and by the speed of thought which is merely the time that network-centric concept works.

Increased awareness of emerging technology will also contribute to leveraging technology to make all of the activities in the value chain more effective and efficient, thus reducing costs and risks. The ability of an enterprise, organization or service to share information across functional areas can enable resource allocation decisions to be made that maximize value from an overall enterprise perspective rather than a purely functional perspective. This ability gains a significant value today, within the continuously increasing global financial crisis that exists.

Moreover, as time is being compressed, the tempo of operations is being increased. Therefore, the cumulative impact of better information, better distribution, and new organizational behavior provides services with the capability to create information superiority. This creates less uncertainty for the decision maker and more knowledgeable entities (individuals or groups), which dominate at the battlespace.

Information age organizations achieve domination of their ecosystems by developing and exploiting information superiority. This research paper presents the concept of dynamic knowledge in military operations and examines the changes in the operating environment, or competitive space of military organizations, and the emerging capabilities that affect people's ability to understand and influence this competitive space recognizing the significant support that information technology offers to this direction.

If one looks at these changes as a whole, it is clear that current missions have become far more complex and the challenges, as well as the adversaries, less predictable. Organizationally, people deal with three distinctive but interrelated levels—the strategic, operational, and tactical. Geographically, they deal with sectors or theaters, and functionally, they usually deal with specific jobs or tasks in a sequential manner (e.g., first comes the suppression of enemy air defenses and achieving air superiority, then attacking other targets is next). The battlespace is thus segmented and one can deal with smaller isolated problems, tasks, or battles. The nature of information age warfare makes it more and more difficult to operate in this challenging and rather unknown environment. The near real-time sharing of information within the enterprise provides decision makers with a common operational picture that helps facilitate self-synchronization, as well as increase the tempo and responsiveness of operations.

For a successful present and a promising future, all nations and military organizations have to know how to get desired results for their goals. They have to know how to assess their situation in a fast and reliable manner, develop credible plans, anticipate the results their plans will produce, implement plans, control execution, observe outcomes, learn from experience, innovate and continually improve. In aggregate, these activities define what Dr. Rick Hayes-Roth (2006) introduces as “efficient thought” (p. 29). What matters most is the ability of the decision maker to achieve good outcomes in a dynamic environment by rapidly and correctly understanding the current situation and its potential evolution. Thus, having the ability to formulate, evaluate, and implement integrated plans and execute them faster than agile adversaries, the decision maker occupies the competitive advantage that offers the final victory.

The modern era has created an environment where collaborative decision making can be employed to increase combat power. This is partly because of the emergence of coalition operations, partly because of the distribution of awareness and knowledge in the battlespace, and partly because of the compression of decision timelines. This alone would be challenging enough, but the information age has also transformed the problem of warfare from a series of static events to more continuous ones by greatly increasing the operating tempo of events. The result is the need for greater integration between the heretofore separate planning and execution processes, which requires more timely interactions between the two, and portends an ultimate merging of these two processes into a seamless form of command and control.

Therefore, reality has changed the way one reaches decisions, allocates decision responsibilities within the organization, develops options and evaluates them, and the manner in which one chooses among them. This has obvious implications in how one designs systems and trains people, which becomes the necessity for more in-depth analysis for their causes.

The technological evolution affects decisions, discovers or generates new areas to invest in, and requires more knowledge that develops a self-reinforcing cycle of research. To this end, it is also true that the continuous race for more knowledge, which decreases the uncertainty, subsequently forces people to rely even more on the technology that provides better, faster and cheaper solutions for the proper management of the received information.

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